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STUDY OF ECONOMIC IMPACTS OF POLLUTION CONTROL ON THE IRON FOUNDRY INDUSTRY

PART II - STRUCTURE OF THE IRON FOUNDRY INDUSTRY

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PART II - STRUCTURE OF THE IRON FOUNDRY INDUSTRY

INTRODUCTION

For the purposes of this study, the iron foundry industry was defined as those shops that melt iron (including iron and steel scrap) in furnaces, pour the molten iron into molds, and alloy and/or treat the iron in either the molten or cast state, with processes limited to making gray, malleable, and ductile cast iron. This definition excludes blast furnace processes, including direct casting of blast furnace metal into molds, and processes for converting iron to steel.

The iron foundry industry possesses many unique characteristics differentiating it from the other industries in the United States. Iron castings, by and large, are high-density items of relatively low cost per pound in the as-cast condition. The economics of long distance transportation of such a product are unfavorable, and result in a wide geographical distribution of iron foundries reasonably close to existing markets. Although there are concentrations of castings producers in the 50 major industrial urban centers, one-third of the foundries are located outside these areas.

The major raw materials required by the industry are almost completely non-strategic, secondary products, available in more than sufficient quantity and of reasonable quality, in all sections of the country where a demand for iron castings exists. These include pig iron, iron and steel scrap, coke, limestone, refractories sand, and clay. In addition, a variety of other raw

materials used in smaller quantities are equally available, including ferroalloys, inoculants, sand additions and fluxes.

The iron foundry industry is dominated by many small producers, with fewer medium-sized foundries, and a relatively small number of very large foundries. The total iron foundry population in 1969 was approximately 1,670, of which 71% can be classed as small foundries with less than 100 employees each, 25% as medium-sized with 100 to 500 employees, and only 4% as large size with over 500 employees. Many of the small foundries are marginal operations with old or obsolete equipment and facilities. In some cases this situation has resulted from the failure of the owners to reinvest a large enough portion of earnings over the years to keep the foundries modern and competitive.

In other cases the production levels of small foundries operating with a low profit margin have not generated enough profits to purchase the necessary equipment to serve this purpose. Furthermore, marginal foundries with poor credit ratings have difficulty in obtaining capital for this purpose. Whatever the reasons for the financial distress of these small foundries, their equipment and buildings have, in many cases, a real value substantially less than the investment required to provide suitable emission controls on their melting furnaces.

Iron foundry population decreased at an average rate of 75 per year from 1947 to 1969, and the statistics show that the decrease was almost completely restricted to the small foundries.

During this period of time, the principal state imposing strict emission control legislation was California in the early 1950's, affecting only a minority of the nation's foundries. It is to be expected that a substantial increase in this historical attrition rate will result from the effect of federal control guidelines when enforcement reaches its full stride.

Pollution control in the iron foundry industry, as in all industries, encompasses air and water pollution. The nature of the foundry process and equipment gives rise to serious problems in the control of air pollution. Water pollution control, on the other hand, is a minor concern since water is generally used only for cooling gases and equipment, and is not an integral part of the process.

(a) Air Pollution

Airborne emissions in iron foundries occur in greatest concentrations and quantities in the melting departments, with cupola emissions the most serious single source. This condition arises from the fact that the heat required to melt metal scrap in a cupola is provided by the combustion of coke in contact with the metallic charge materials. Not only are combustion products such as carbon monoxide, carbon dioxide, water vapor and ash swept up the stack, but also some non-combustible products like limestone dust and dirt or sand. In addition, some unburned combustibles like coke dust and oil vapor are exhausted along with some extremely fine, precipitated metallic oxides.

Emissions from other types of melting equipment, such as direct electric arc furnaces and electric induction furnaces, are substantially less than cupolas, as combustion does not occur in the furnace. Current technology makes possible the ability to capture the particulate emissions from melting equipment to the degree necessary to satisfy state and local codes, although at a cost averaging approximately 5% of the value of the castings produced.

Particulate emissions result from a number of other foundry processes, but in smaller amounts. These sources have been more or less satisfactorily controlled in the past, using technology that has been developed for some years. Not only is the cost of this control usually lower than that for melting furnaces, (because of the lower concentration and larger particle size) but the emissions occur mostly in the building and tend to settle out before they are exhausted to the atmosphere.

(b) Water Pollution

Separation of particulate emissions from the melting department, or in the foundry building is usually achieved by the use of either fabric filters, cyclones, or wet scrubbers. In the case of the first two, the process is a dry one, and no water is required or used. Water is, however, used in a wet scrubber and is separated from the collected particulate matter by a variety of methods including settling, decantation, and filtering. The equipment used for this purpose is a part of the air pollution control equipment. The clarified water is

recirculated for use in cooling melting furnaces such as water-cooled cupolas and electric arc or induction furnaces, or for slag granulation. Water pollution is a minor problem in foundries for three reasons:

1. A relatively small amount of water is contaminated.

2. Contaminants are virtually all particulate matter, relatively easy to separate.

3. Water clarifying equipment is furnished with the air pollution control systems, and the clean effluent from these systems is recirculated.

Installation and operating cost data for air pollution control systems used in this report include associated water pollution control costs.

(c) Other Types of Pollution

The physiological damage resulting from extended exposure to loud noise has been recognized legally in the Occupational Safety and Health Act of 1970. Many foundry operators, aware of the noise conditions inherent in their operations, have planned to install or have already begun to install controls to protect their employees. Little data are available on which to estimate industry costs for this control, and they are not included in this report. Radiation control is not a major concern for the iron foundry industry since few companies use radiation test equipment. Control of radiation consisting of special construction

universally provided to house the equipment has long been considered a part of the equipment installation cost.

A - DEMAND FOR IRON CASTINGS

CAST IRON PRODUCTS AND SUBSTITUTE PRODUCTS

Iron castings include an extremely wide range of products. The primary breakdown of cast iron products includes cast iron molds for the pouring of steel ingots, cast iron pressure pipe, cash iron soil pipe and miscellaneous castings as tabulated in Exhibit 1. A further breakdown of miscellaneous castings, if available, would list thousands of products in hundreds of categories. An indication of distribution of miscellaneous castings by industry is provided by the tabulation in Exhibit 2. The wide distribution among industries is evident from the fact that only 66% of the casting production is accounted for by 30 major industries, with 2,531,000 tons per year distributed among all other industries.

Most iron castings are components of finished products. Only a relatively few, such as ingot molds, cast iron pipe, some fittings, cast iron annealing boxes and machinery weights, are complete and finished products when shipped from the foundry. The remainder, purchased by other industries as detailed in Exhibit 2, include such items as machinery bases and housings, machine elements, gear and sheave blanks, engine blocks, brake drums hardware, and a host of others. The complexity of the castings varies from simple forms requiring little or no core work to complex shapes with many insets, holes, interior passage-ways, and protuberances. The selection of iron as the material and casting as the manufacturing process is often based on the

particular characteristics of the product and/or cost or ease of molding compared to some other fabricating method. Quantity of identical, or nearly identical parts required is often a criterion in the selection of the process, with large quantities lending themselves to the casting process.

In most cases cost increases of approximately 5% will not affect the selection of cast iron for a product, particularly if the quantities are great and the shape complex. Although price increases of this magnitude might be expected, in order to offset the installation and operating costs of emissions control equipment, somewhat similar costs will undoubtedly be associated with a substitute material and process. Even though the control costs for the alternate were only half those of iron castings, the differential would be expected to have a minor effect on the use of the majority of iron castings.

Iron, as a material, has desirable physical and chemical characteristics resulting in its use under certain conditions almost independent of its cost. Its vibration and shock dampening capacity due to the graphite inclusions makes it a highly desirable material for presses, forges, and machine tools. Its corrosion resistance permits its use in underground or underwater applications without special corrosion-resistant coatings. The same characteristic, in addition to its strength, explains its wide usage as pressure pipe in potable water distribution systems and as sewage or drainage pipe. It is universally used for brake drums because of its heat, wear, and warping resistance. Iron's wear resistance also dictates its use in some types of

bearings, cylinders and piston rings, gears and as machine ways or slides. Chilled cast iron has superior wear and abrasion resistance at the expense of an increase in brittleness. Iron is also highly machinable due to its heterogeneous structure, resulting in chip formation rather than continuous turnings.

Despite these advantages, the use of some substitutes occurs under certain conditions, such as the quantity required of a single item, and its complexity. In addition, some traditional uses of cast iron have been offset in recent years by technological advances in metallurgy and surface coating, and the development of synthetic materials. The principal products in which competitive materials are widely used are cast iron pressure and soil pipe. In these products lined steel pipe and non-metallic pipes of asbestos-cement, prestressed concrete, vitrified clay and plastics are widely used.

THE MARKET FOR IRON CASTINGS

The total market for iron castings has not been accurately identified due to its fragmented quality, and the fact that many industrial users of castings operate their own foundries, for which production data are not available. For many years, however, industry capacity has substantially exceeded the demand and because of this condition the market can be equated to annual production to the extent the total output can be identified. Shipments of iron castings for the years 1960 to 1970 inclusive are tabulated in Exhibit 1. The table shows shipments of

11,288,000 tons in 1960 increasing to 15,048,000 in 1965, and then decreasing more or less steadily to 12,873,000 tons in 1970.

Iron foundry casting production and number of foundries for other countries are tabulated in Exhibit 3. The dollar value of imports from many of these countries is shown in Exhibit 4 for the period from January to April 1968. A summary of U.S. imports from 1961 to 1967 is listed in Exhibit 5. Imports and exports for three months of 1968, by weight and value, are shown in Exhibit 6. Omitting the import of pig iron, which is a foundry raw material rather than a product, the total imported castings are 19,200 tons for this period, or 76,800 tons on an annual basis, amounting to slightly over one-half of one percent of the industry total. Foreign imports by these statistics would represent minor competition to the U.S. foundry industry. It is believed, however, that imports have been understated, since many castings shipped from foreign sources are not identified as castings but rather in terms of their end use. The total of import shipments incorrectly identified is not known, but is believed to be a significant quantity.

DISTRIBUTION OF IRON CASTINGS

Virtually all iron castings, with the exception of ingot molds, pipe and pipe fittings, are single-purpose items purchased to exact specification, each with regard to weight, configuration, and analysis as a component in a product manufactured by the purchaser. The design of the casting is proprietary and the

pattern used to form the cavity in the mold is often owned by the purchaser. The distribution system for these castings is simple direct sale by the foundry to the purchaser who generally performs the required machining and finishing operations required for its assembly into the purchaser's product.

A minor amount of warehousing is often provided as a service to the purchaser by the job shop foundry, especially when the total order quantity is large compared to the short-time delivery requirement. In the event the economic manufacturing quantity is larger than the immediate delivery requirement this service is also offered as a means of lowering the unit cost and thus improving the foundry's competitive position.

Distribution of castings produced by captive foundries is an internal operation. Some castings are distributed by the final product manufacturer as replacement or spare parts. Commonly this is also internal to the manufacturer as in the case of an automotive casting stocked by the manufacturer and then sold by a dealer to the end user.

Miscellaneous castings including ingot molds account for approximately 66.3% by weight of total iron castings production. Tentative industry production totals for 1970 are 12,873,000 tons of gray, ductile and malleable iron castings of which 8,531,000 tons are identified as miscellaneous castings.

Ingot molds represent 11.4% of the total, and cast iron pipe and pipe fittings represent the remainder of the total

iron casting production in 1970, amounting to 3,015,000 tons, or approximately 23.4% by weight. These products have been standardized and distribution systems are different and more complex.

Cast iron pressure pipe is manufactured by about 30 specialty foundries. Most of the product is warehoused by the manufacturers and sold direct to cities, states and other governmental entities, such as city utility companies or to their contractors. A very small portion of the pipe production is sold by the producer to industrial plumbing distributors or contractors for connection of major building projects to city water systems. Pressure pipe represented approximately 14.9% of total iron casting production in 1970.

Cast iron soil pipe, representing about 7.4% of total iron castings in 1970, is manufactured by 20 special foundries, and is sold by the manufacturers to distributors and contractors.

Castings for cast iron pipe fittings are virtually all cast by fitting manufacturers. Valve bodies after machining are assembled with other components to make up the complete valves. Certain fittings have no components other than the iron casting and require only machining to become a finished item. Fittings are sold to plumbing and heating wholesalers, and to contractors purchasing in large quantities. Cast iron pipe fittings accounted for 1.1% of the total iron casting production in 1970.

Ingot molds are all sold to steel plants, and are generally produced to order and shipped directly from the foundry to the user. Molds produced from gray iron are made in 15

foundries. Ingot molds, pipe and fittings, representing about 34% of total iron tonnage are produced in about 65 foundries, or under 4% of total foundries.

MARKET TRENDS

The growth of production in the iron foundry industry has been projected by estimating the growth rates for each of the principal segments identified previously, based on the growth of the user industry identified with that segment. The three were then combined to provide the input for the total estimated growth. Total iron castings production, excluding ingot molds made from direct blast furnace iron, has been projected to be approximately 17 million tons per year by 1980, or an average of 2% increase per year, as shown in Exhibit 7.

Iron castings production growth, as measured by tons per year of output, has been somewhat behind the trends of some of the other industries, and has not kept up with the trends shown in the early 1950's. This has probably been caused, in part, by competition from other products and materials, such as steel weldments, nonferrous castings and nonmetallics. The relatively moderate increase in tonnage of output has also been caused by the improvement in technology which has enabled thinner wall iron castings to be produced, resulting in an increase in the number of castings per ton of weight. On a basis of quantity of castings, therefore, the growth of output of the iron foundry industry has more than kept up with the national gross product growth.

The number of iron foundries which will be in operation by 1980 has been projected to be approximately 1,000. Since the number of medium- and large-sized foundries has been projected to increase slightly, the entire drop from the 1969 total of 1,630 foundries to 1,000 foundries is expected to take place among the small-sized companies. The combination of increasing output and reduced number of producers is expected to continue to increase the average output per foundry to an estimated 16,500 tons per year by 1980. This is almost four times the average production immediately after the war.

GOVERNMENT INFLUENCE ON THE IRON CASTINGS MARKET

Although government influence on a product market can be achieved in many ways, and for many reasons, such influence in the United States at this time is commonly due to one or more of the following conditions:

1. The raw materials or finished product have strategic value such as war materiel, fissionable material, or the ability to hasten the depletion of a natural resource, such as helium, oil or certain metallic ores.

2. The government can be a major purchaser of the product with the concomitant influence on acceptable price levels.

3. The government can influence the use of alternate products at lower cost by specification or establishing of budget ceilings for government projects, or those projects sponsored or guaranteed by the government.

Iron castings are not affected by the first of the three conditions since the raw materials are secondary products, in plentiful supply, and without strategic significance.

The second condition does not generally pertain to miscellaneous castings since the government is not a large purchaser of iron castings as such. Many governmental purchases are for products in which iron castings are minor components, but market price influence for these components is indirect and of minor consequence.

The market for cast iron pipe products is more subject to local, state or federal governmental influence than other segments of the industry. This influence derives partly from the fact that governmental bodies purchase or control the purchase of pressure pipe for potable water systems, and soil pipe for sewage systems. In addition, the Federal Housing Authority, in its function of guaranteeing residential mortgages, exerts some influence in the selection of least cost materials.

A number of substitute materials with different physical and chemical properties compete with cast iron pipe in the pressure pipe field, including lined steel pipe, asbestos-cement pipe, prestressed concrete pipe, and fiberglass reinforced plastic pipe. Asbestos-cement pipe, plastic pipe and vitrified clay pipe compete with cast iron products in the soil pipe area. The selection of one material over the other for these applications is primarily an engineering judgement on the basis of the

severity of service. A selection based wholly on material cost on the other hand could result in an unsatisfactory system life, and the need for early replacement.

B - SUPPLY OF IRON CASTINGS

DEFINITION OF INDUSTRY STRUCTURE

(a) Production Process

The iron foundry consists of a number of distinct but strongly interconnected operations. All foundries utilize certain basic operations consisting of:

1) Raw material storage and handling.
2) Melting.
3) Pouring into molds.

Other processes present in most, but not all, foundries include:

1) Molding.
2) Sand preparation and handling.
3) Mold cooling and shakeout.
4) Casting cleaning, heat treating, and finishing.
5) Coremaking.
6) Pattern making.

A simplified, schematic flow diagram encompassing most of these processes is presented in Exhibit 8.

Each operation contains equipment and processes capable of producing emissions which may include gas, fume, smoke, vapor and particulate matter. The latter can range from metal dust from grinding operations that is relatively easy and inexpensive to collect to extremely fine ferrous and nonferrous oxides from melting furnaces that are very expensive and difficult to collect. The sources of these emissions are schematically indicated in Exhibit 8, and the operations are described in the following paragraphs.

(1) Process Flow for Gray, Ductile and Malleable Iron

The basic process flows for gray, ductile, and malleable iron are shown in Exhibit 9. In general the flow is similar for each of the three types of iron, except for the variations shown in the exhibit.

The most common flow pattern in the iron foundry industry is the one for gray iron production. The process flow for ductile iron differs from gray iron principally by the addition of two operations--the magnesium treatment to nodularize the graphite in the iron, and the press straightening which is sometimes required.

Malleable iron process flow is also similar to gray iron flow with the exception of an annealing operation required to convert the as-cast "white" iron into malleable iron, and the press straightening sometimes required to correct the warping

that results from the annealing process. In other regards the process flow for malleable iron is the same.

(2) Process Flow and Descriptions of Basic Foundry Operations

Brief descripticns of the operations are given on the following pages.

Raw Material Storage and Furnace Charge Preparation

Raw Material Receiving and Storage

The raw materials used for iron production fall into the following classifications:

1. Metallics, including pig iron, iron and steel scrap, turnings and borings, ferroalloys, foundry returns and alloys.
2. Fluxes, including carbonates (limestone, dolomite, soda ash), fluorides (fluorspar), carbides (calcium carbide).
3. Fuels-Coke (for cupolas).
4. Refractories.

These materials, except for foundry returns, are received by railcar or truck, and are unloaded and stored in the foundry scrapyard. Covered storage is desirable for induction melting scrap which must be dry when charged into the furnace.

Scrap Preparation

For the most part, scrap materials, including foundry returns, are used in the as-received form. Many scrap dealers

prepare scrap to foundry specifications, thus eliminating any need for additional preparation by the foundry. Where scrap preparation is required, the operations may involve any combination of the following:

1. Cutting to size by flame torch, shear, breaking, or fragmentizing.

2. Cleaning by degreasing, steam or by shot-blasting.

3. Burning of surface coatings or oils.

4. Drying or preheating.

With the exception of the cutting operations, scrap preparation is not widely performed for cupola melting, or for top charged electric arc furnaces. However, for electric induction furnaces, a greater degree of preparation is necessary to obtain dry, clean scrap of the proper size.

Furnace Charge Preparation

The methods of makeup and handling of melting furnace charges vary widely from completely manual systems where all materials are hand shoveled or carried, to highly mechanized systems where one man can control the handling, weighing, and loading of all raw materials.

Charges are normally loaded directly into the furnace charging bucket, skip, or similar container. The prescribed combination of metallics, flux, and coke (for cupolas) is weighed either before loading or while loading.

Where preheating or drying operations are performed, they are commonly done directly in the charge containers. This can be accomplished by heating from above with a flame or radiant burner, or by use of a double-walled bucket in which combustion is accomplished within the wall cavity. Other methods include the use of rotary dryers, heated conveyors, and preheat furnaces.

Iron Melting

A 1968 study, covering about 75% of all foundries, showed the following distribution of melting furnaces in the iron foundry industry.

Iron Foundry Melting Furnaces - 1968

Furnace Type	Number Installed	Percent of Total
Cupola	1,232	89.5%
Electric Induction	73	5.3
Electric Arc	42	3.1
Other Types	29	2.1
Total	1,376	100.0%

The furnace census does not show the number of reverberatory furnaces in use, but it would be expected that they constitute the majority of the 2.1% indicated as "Other Types". Despite the low incidence of use, this method of melting is of interest because of its reported low emission of particulate matter, and its increasing use in small foundries.

The reverberatory furnace is heated by coal, natural gas or oil, while the induction and arc furnaces obtain their heat from an electric induction coil or an electric arc. In the cupola,

coke is a portion of the furnace charge and the heat required to melt the iron is derived from the combustion of the coke in contact with the metallic and fluxing charge materials.

The molten metal from the furnaces is tapped directly into a ladle for direct mold pouring, into a transfer ladle for conveying to the molding area, or into a heated or unheated holding device.

From a cupola, the hot metal can be transferred to a forehearth, an electric induction or arc furnace for holding, or into a reverberatory duplexing furnace if the final product is to be malleable iron. With the exception of the forehearth, a similar selection of holding or duplexing furnaces is available for electric or fuel fired melting furnaces. As the metal is available and required, it is removed from the holding or duplexing furnaces for transfer to the molding area.

Cupola Furnaces

The cupola is a vertical furnace with a normally circular cross section which is charged alternately with metal to be melted, fuel in the form of coke, and a fluxing material, to produce molten iron of a specified analysis and temperature. Many fundamental cupola designs have evolved through the years, two of which are widely in use at this time--the conventional refractory lined cupola shown in Exhibit 10, and the more recent development, the unlined, water-cooled cupola, shown in Exhibit 11.

Electric Arc Furnace

Description. The direct arc electric furnace, shown in Exhibit 12, consists of a refractory lined, cup-shaped, steel shell with a refractory lined roof through which three graphite or carbon electrodes are inserted. The shell is arranged for tilting to discharge the molten metal. Charging of the metal is accomplished by chuting through a door opening in the side of the shell, for fixed roof furnaces, or by raising the roof and swinging it aside to permit the use of a bottom dump charge bucket for removable roof furnaces. The furnace is provided with a tapping spout and a working door, with a second door for large furnaces.

Induction Furnaces

Description. The induction furnace is a cup- or drum-shaped vessel that converts electrical energy into heat to melt the charge. Unlike the electric arc furnace, no electrodes are required. The induction furnace converts electrical energy into heat by utilizing the transformer principle in which a magnetic field is set up when the primary coil of the transformer is energized. The magnetic field at a high flux density induces eddy currents in the charge which are converted to heat by the electrical resistance of the charge itself. The channel induction furnace is illustrated in Exhibit 13, and the coreless furnace in Exhibit 14.

Reverberatory Furnace

The reverberatory type of fuel fired furnace is found in two types of applications in the iron foundry. The large, stationary reverberatory or air furnace is associated with malleable iron foundries, where it has long been used as a duplexing unit in conjunction with a cupola. These furnaces are long, rectangular units with arched or suspended roofs, generally fired from one end, and with waste gases exhausting into a stack from the opposite end.

The second type of reverberatory fuel fired furnace, illustrated in Exhibit 15, is used for melting. It is generally small in size, up to two tons capacity, and tilts for pouring. Furnaces of this type are found in small foundries where economical installations and low emission melting are desired.

Molding, Pouring, Cooling and Shakeout

Many molding materials and types of equipment have been developed for the production of iron castings. Major techniques found in current practice include green sand, dry sand, shell, and hot box.

Green Sand Molding

Of all the types of molding in use today, by far the greatest tonnage of castings is produced from green sand molds. They are commonly made of silica sand, clay, water, and organic binders such as cereal binders mulled together to form a moist

mixture suitable for use with manual or automated molding machines and sand slingers. Green sand molds are the least costly of all molds to produce.

Centrifugal Casting

Cast iron pressure and soil pipe is normally made in permanent molds. The molds are rotated rapidly about their longitudinal, horizontal axis during the pouring and cooling cycles producing a dense, high quality casting. A dry sand or shell sand core is inserted in the mold to form the bell end of the pipe only.

Dry Sand Molding

Dry sand molding is usually applied to thick section castings of fairly large size or weight such as machine beds, cylinders, and heavy gears.

Shell and Hot Box Molding

The shell molding process for making castings is used where dimensional accuracy and surface finish of the part is important. This molding technique has found wide acceptance in the foundry industry. The sand used consists of a mixture of dry sand grains and synthetic resin binder. The resin must be a thermosetting type since the strength developed by the mold depends entirely on the strength of the binder after the mold has been heated.

Pouring and Cooling

In a high volume production foundry, finished molds are set out on continuous car-type or indexing mold conveyors, or on pallet conveyor lines. In smaller production and jobbing foundries, completed molds are set out on the foundry floor or on gravity roller conveyors.

In mechanized production foundries the molds are usually poured within minutes of completion. Most small foundries, however, may pour only a few hours a day or only two or three days a week. In these cases the molds are usually set out on the foundry floor until hot metal is available.

Shakeout

In many foundries the casting is separated from the molding sand manually. Even in partially mechanized foundries where completed molds are set out on gravity roller conveyors for pouring and cooling, the molds are dumped manually and the castings picked or hooked out of the sand and placed in a tote-box for further cooling and moving to the cleaning room.

Larger and more mechanized foundries tend to use a heavy-duty vibrating screen for shaking out. The sand flows through the screen openings to the return or shakeout sand system, for transfer to the sand conditioning system. The castings are removed from the shakeout grid manually, by a hoist or by action of the vibrating screen, for cooling and sorting.

Sand Conditioning

Sand is a basic foundry material used in substantial volume by almost all foundries as a molding medium. The complete sand system consists of receiving and storage facilities, molding sand preparation, and the handling equipment required to transfer the sand to its points of use, preparation, and discard. In addition, some high production foundries using very large amounts of sand have reclamation systems for returning used sand to its original condition, or as near to it as is practical and economical.

Sand Preparation

In past times, naturally bonded molding sand was universally used for green sand molding. Preparation of the sand for reuse consisted of adding water and some new sand to replace the amount sticking to, or embedded in, the surface of the castings. This sand has been almost completely replaced by clean silica sand to which is added water and the various binders required to produce the desired molding characteristics.

Sand preparation in the majority of today's foundries is accomplished on the foundry floor by adding moisture, binders, and new sand to the used sand. A number of types of mobile and portable equipment is used to cut, screen, mix, and aerate the sand to prepare it for reuse.

Mechanized foundries are generally equipped with fixed sand preparation equipment to which the shakeout and spill sand

is transported by conveyors and elevators. After preparation, including magnetic separation of tramp iron, screening, addition of binders and moisture, mulling, and possibly aeration, the prepared sand is conveyed to the molders.

Cleaning, Heat Treating and Finishing

Cleaning and finishing of castings are the final operations performed in the foundry. Cleaning of castings generally refers to the operations involved in the removal of sand and scale: sprues, gates, and risers; and fins, wires, chaplets or other metals not a part of the casting. The castings, after they have been separated from sand at the shakeout screen, are cooled in boxes or on a conveyor which moves them to the cleaning and finishing area.

Cooling and Sorting

Following shakeout and sprue removal, castings are cooled before being sent to the cleaning and finishing area. Cooling can be accomplished in a variety of ways, depending on the size and shape of the castings, the rate at which castings are produced, and the degree of mechanization in the foundry.

Castings Cleaning

The removal of sprues, gates and risers is usually the first operation in the cleaning room. This is done by impact, shearing, abrasive cutoff, band or friction sawing, or torch cutting

depending upon the size of the casting and the type of iron. Abrasive cutoff wheels can be used for removing gates and risers on castings made of hard- or difficult-to-saw alloys. Gates and risers on large ductile castings are most conveniently removed by gas cutting. Band or friction sawing may be used where it is desirable to follow the contour of the casting.

Surface cleaning operations ordinarily follow removal of the gating system for all foundry castings except malleable iron castings which are heat treated before surface cleaning operations. Abrasive operations such as shotblasting, sand blasting, and tumbling are normally used. Wire brushing, buffing, pickling and polishing operations may also be performed in some cases.

Heat Treating

Iron castings are heat treated to improve physical characteristics and to improve machineability. Typical heat treating temperature ranges for gray iron are:

Stress Relief	1000°-1250° F
Anneal	1250°-1725° F
Normalize	1725° F
Quench and Temper	1550°-1600° F

Annealing of white iron castings to produce malleable iron is done at 1600°-1750° F. Batch-type or continuous furnaces may be used depending upon the type of heat treating and production requirements.

Casting Finishing

Following surface cleaning and heat treating, castings are finished to remove gate and riser pads, chaplets, wires, and parting line flash not a part of its final dimensions. Chipping hammers and grinders are used for these operations.

Casting Coating

The large majority of iron castings are ready for shipment after finishing operations are completed. Some casting specifications, however, require that a surface coating be applied for rust proofing or other reason. Rust preventive paints are usually applied by spraying, fogging, or dipping, depending upon the type of coating, casting size and shape, and production requirements.

Coremaking

Cores are normally made of silica sand and organic or inorganic binders. The selection of the core formulation and process best suited to a particular application requires consideration of many factors including green strength, dry strength, porosity, core complexity, quantity of cores required, and raw material, equipment and production costs.

Core Processes

The major coremaking processes in current use for castings are oil sand, shell, silicate bonding, furan, hot box, alkyd, and phenol. Selection of the appropriate process for a given core is based on the above factors.

Pattern Making

Foundry patterns are normally made of wood or metal. Patterns for small production runs tend to be the former and for large production runs, the latter. Wood patterns generally have a shorter useful life, although they can be repaired more easily than the metal patterns which usually have a higher first cost. A large production requirement, however, often results in a lower pattern cost per mold with metal molds.

Typical pattern making steps include cutting the wood or metal pieces to size, fastening the pieces together, and painting, varnishing and mounting where required. Match plates are often cast from the original patterns.

Wood pattern shop equipment includes different types of saws, planers, joiners, lathes, edgers, routers and drill presses. Metal pattern making equipment includes typical machine shop tools.

(b) Type and Location of Raw Materials

The major raw materials used in producing iron castings are pig iron, ferroalloys, coke, iron and steel scrap, limestone, and sand. Minor raw materials include metallic alloys, dolomite, soda ash, fluorspar, calcium carbide, sand, clay, cereal binders, chemical binders, and core oils.

Pig iron is iron produced in a blast furnace as a preliminary step in the manufacture of steel. A portion of the molten iron

from the blast furnace, with the composition specially developed for foundry use, is poured into metal molds, and the cooled blocks or "pigs" are sold to foundries. The geographical sources of pig iron and ferroalloys, tabulated in Exhibit 16, are essentially steel mill locations. The sale of the product is handled by distributors and is readily available to foundries located any place in the country.

In the days when coke was used for domestic heating it was produced in all locations where suitable coal was to be found, and local coke was readily available to foundries. With the passing of the widespread demand for coke, the number of producers decreased. Now, metallurgical coke is manufactured by the steel producers for their own use and for sale to foundries and other users, and by a small number of specialty companies in locations shown in Exhibit 16. This raw material is also sold by distributors and is easily available to all foundries in the country.

Most other foundry raw materials are local in origin. Ferrous scrap is available in all locations where ferrous products are used. Almost every town and city has at least one scrap dealer who collects locally and sells either locally or ships the scrap to nearby urban areas where the demand is greater. In addition to purchased scrap, each foundry produces scrap iron from casting gates and risers and scrap castings. This material, amounting to as much as 50% of the finished casting weight, is returned to the melting department for remelting and

pouring. Captive foundries often obtain scrap from manufacturing operations of the parent company.

Limestone is found in almost all sections of the country. It is quarried, separated, crushed, graded and washed for local foundry use as well as for aggregate in concrete and other uses. Some foundry melting processes require additional fluxes other than limestone. These include dolomite, soda ash, fluorspar and calcium carbide. These materials are also found in many parts of the country and require minimum transportation to foundries.

Silica sand, used for molding and core making, is essentially a local product. In the past when natural bonded sand was used, sand of the correct grain size and shape and with desirable amounts of clay binder well distributed among the grains was shipped long distances by rail to foundries. Now a clean silica sand of the proper grain size obtained naturally or crushed and screened to size is universally used. Various binders, both clays and grain cereal flours are used for molding sand. Silica sand similar to that used for molding, except with different grain size and sharpness is used for making cores. Core binders include oil, cereals and chemicals. Sand suitable for these purposes can be found in all parts of the country. Cereal binders are essentially cornstarch and are milled in various locations. Clay binders are either local or are special clays called bentonite, found in Wyoming, North Dakota and Mississippi.

Chemical binders for both molding and core sand are more widely used each year. These materials are manufactured in many areas and sold by distributors who warehouse many compounds in all areas of the country where the concentration of foundries creates a sufficient demand.

Metallic alloys used widely in iron foundries to obtain desired chemical analyses are manufactured in scattered locations. They are prepared to standard analyses by metal refiners and re-refiners. Sale of the alloys is often handled by distributors or representatives and the alloys are shipped direct or from regional warehouses depending on the quantities involved.

Raw material expenditures and quantities used in the years 1963 and 1967 by gray and malleable iron foundries included in SIC 3321 and 3322 are detailed in Exhibit 17. These are not industry totals since captive foundries are not included in the SIC numbers for which this information is available.

(c) Population and Location of Iron Foundries

The population trends in the foundry industry have been developed in Exhibit 18. The total number of foundries of all types has remained relatively constant during the postwar period, ranging from 5,000 to 5,800 and averaging approximately 5,400. However, the iron foundry population has shown a steady decline, from 3,200 in 1947 to 1,670 in 1969. If this decline continues, the number of iron foundries is projected to be approximately 1,000 by 1980.

An analysis of the population of iron foundries with respect to size of foundry has shown that almost the entire decline in foundry population has been among the small foundries with employment of under 100 per foundry. The number of medium-sized foundries has remained almost constant, while the number of large foundries has increased slightly. The number of small foundries had declined by one-third from 1959 to 1969, and is expected to further decline to only about half of the 1969 population by 1980.

The distribution of iron foundries by states and by major metropolitan areas is shown in Exhibit 19. The highest concentration is in the states which border on the Great Lakes, namely, Pennsylvania, Ohio, Michigan, Illinois, Wisconsin, New York and Indiana. This group of seven states contains almost half of all of the iron foundries in the United States and more than half of the iron castings capacity. The state of California contains the greatest concentration of iron foundries in the western half of the country, with one-third of the iron foundries in that 17-state area being in California. Other areas of high iron foundry concentration are in the southeastern states and in the northern states bordering on the west bank of the Mississippi River.

The locations of the principal concentrations of iron foundries have been pinpointed into major metropolitan areas. A total of 50 such areas accounts for more than two-thirds of the iron foundries. Here again, the principal concentration is in

the industrial cities in the seven Great Lakes states, with two-thirds of these centers being in, or bordering on, those states. It is of further interest to note that the decline in number of iron foundries in these areas was a considerably lower rate than for the balance of the country, emphasizing the fact that the greatest mortality in iron foundries has been among the smaller companies located in the smaller metropolitan areas.

The variations which have occurred in the distribution of iron foundries by states during the period of 1963-1969 are given in Exhibit 20. State and regional totals for 1970 are tabulated in Exhibit 21.

(d) Types of Iron Foundry Companies

An examination of such factors as size, integration, single or multi-plant, single or multi-product, diversification, and the stage in the manufacturing process in which industrial companies operate, can serve to characterize an industry and its producers.

1. Company size. Size distribution of iron foundries by value of production and number of employees is tabulated in Exhibit 22. These data are for individual foundries, and are not readily available for foundry companies. Exhibit 22, Item 4 shows that 22.4% of the foundry companies in 1963 operated more than one foundry, and that the percentage had increased to 26% in 1967. This trend largely reflects the decreasing population of small single unit foundries. Additional data are tabulated in Exhibits 23 and 24 showing employment, wages, value added, and

relationship of foundry employment and production.

2. Degree of Iron Foundry Integration. An integrated plant is one that produces finished products from primary raw materials. Foundry raw materials have been identified in earlier sections of this report as being virtually all secondary products. Final foundry products with the exception of a few cited products are components of products, in large part, manufactured and assembled by the foundry customer. On this basis, few if any, integrated foundries exist.

3. Single or Multi-Plant Operation. The ratio of 26% multi-plant to 74% single plant iron foundries in 1967 has been discussed above in the section dealing with size of iron foundry companies. The trend toward multi-plant companies if projected on a straight-line basis would result in 30% of the companies thus classified for 1971. It is believed that this proportion has not been achieved to date. However, with the projected closing of 500-600 small foundries by 1981, multi-plant foundries will be a substantially larger portion of the foundry population, probably in the range of 35% to 40%.

4. Production of Single or Multiple Products. Foundry companies are essentially single product manufacturers. Pipe foundries representing slightly over 22% of the industry in terms of output produce only cast iron pipe, although in a variety of diameters, lengths and metal analyses. Jobbing foundries similarly produce only castings, again in a variety of weights, sizes, configurations and metal analyses. Captive foundries producing approximately 40% to 50% of the industry output may manufacture

castings for more than one division of the owner company but, despite the number of different patterns used, produce only castings. The owners of the captive foundries usually manufacture more than a single product. Gray iron and malleable iron foundries, SIC codes 3321 and 3322, have specialization ratios of 93% and 85% respectively. The manufacture of products outside the respective classifications, however, does not represent non-foundry products but, rather, limited production of castings of other materials.

5. Diversification. Foundry companies generally diversify only to the extent they produce castings for different industries or of different metals. Owners of captive foundries are in many cases widely diversified but the foundries themselves commonly produce a single class of castings, usually of a single metal. Statistical data on diversification is not readily available.

6. Stage in the Production Process. With the exception of companies producing cast iron pipe or ingot molds, iron foundry companies do not manufacture finished products but rather components for their purchaser's product. This is also true for multi-plant foundry companies since the additional plants are almost always foundries too. Only the 22.3% of iron casting production representing cast iron pipe, and the 11.4% representing ingot molds are finished products.

(e) Types of Iron Casting Plants

The plants producing iron castings can be characterized by

consideration of several factors including size, age of facilities and equipment, the level of technology employed, efficiency of the operation, and the proportion of the total production process accomplished.

1. Size. Employment statistics, tabulated in Exhibit 22, Item 2, show that in 1959 80% of the foundries had fewer than 100 employees, 17% with 100 to 500 employees, and 3% with more than 500 employees. In 1969 the corresponding employment percentages were 71% for fewer than 100 employees, 24% for 100 to 500 employees, and 4% for more than 500 employees. The decrease in the percentages for small foundries reflects the closing of 560 small foundries and the increase of 35 foundries in the medium and large categories, in the interim period. Also noteworthy is the fact that slightly under 50% of the foundries operating in 1969 employed fewer than 50 people.

The data in Exhibit 22 were adapted from information reported by Foundry Magazine to exclude Canadian foundries. U.S. Department of Commerce data shown in the exhibit include only those foundries in SIC 3321 and 3322 and do not include captive foundries. The percentage derivations of these data, however, closely corroborate the broader industry statistics provided by the industry journal.

2. Age of Foundry Plant Facilities and Equipment. The age of selected foundry equipment in December 1967 is tabulated in Exhibit 25. The data cover all foundries in the United States and Canada including iron, steel and nonferrous foundries. Experience suggests, however, that the data are essentially accurate for iron foundries in the United States. Cupolas are

used exclusively in iron foundries so these data can be used without reservations.

Cold blast cupolas have been the basic iron melting furnace for more than 100 years and even today outnumber other more recent innovations for this purpose such as hot blast cupolas, electric arc and induction furnaces. The data show that 41% of the cold blast cupolas are over 20 years old and 71% are over 10 years old. The stationary reverberatory or air furnace, has long been the standard method of duplexing iron in the manufacture of malleable iron, and also shows a high average age. The age ranges of hot blast cupolas and induction furnaces reflect their relatively recent development.

Core and mold ovens are gradually being phased out as more and more foundries adopt the newer molding and core making processes not requiring this type of equipment.

The severe operating conditions in foundries resulting in a shortened useful life for many pieces of equipment are reflected by the age ranges for many units. These pieces of equipment include shakeouts, airless blast machines, grinders, portable tools, sand rammers, and fork trucks. The comparatively recent development of shell and hot box core machines is also indicated by the age ranges of this equipment.

Heavy cranes of 5-ton capacity and greater are seldom replaced, although many have been rebuilt electrically to convert to alternating current from the original direct current, to modernize the controls with more efficient and safer equipment, or to increase the operating speeds. For this reason the age range of foundry buildings is more closely related to the age of the heavy cranes than to other equipment.

The exhibit shows such a wide range in the average age of equipment that no generalization is possible, but indicates that most foundry buildings are old and probably obsolescent. Conclusions as to the age of specific types of equipment are as follows:

(a) Cold blast cupolas have a high average age with 71% over nine years old. Most of these units are in small- and medium-sized foundries. It is estimated that few will be replaced by the same type of equipment. Many cupolas of this type are in small, marginal foundries that will close down in the next few years. The foundries that survive will replace the old cold blast cupolas with coreless induction furnaces or hot blast cupolas.

(b) Hot blast cupolas have an average age of less than eight years. Few will be purchased in the near future, due in part to the low average age and the general trend toward induction furnaces.

(c) Reverberatory furnaces include the large stationary type used for duplexing purposes in malleable iron foundries, and the small tilting type used for general melting. Ductile iron is gradually replacing malleable iron due to its lower manufacturing cost, and the large old air furnaces will probably not be replaced. Sales of small tilting reverberatory furnaces will increase slightly to partially replace old cold blast cupolas.

(d) The low average age of direct arc furnaces shows the recent acceptance of this type of furnace in the iron foundry.

(e) Channel and coreless induction furnaces have low average ages reflecting their recent development and the strong trend toward these furnaces for replacement of cupolas. These furnaces usually do not require emission control equipment.

(f) Core and mold ovens have a high average age and are becoming obsolete due to technological change in both core and mold making processes.

(g) Molding machines for green sand molding have a high average age and many are obsolescent.

(h) Core blowers and shooters also have a high average age greater than 10 years, but do not have as high a degree of obsolescence as molding machines.

(i) Shell and hot box core machines are a recent development and represent a high current technology.

(j) Bridge cranes of over 5-ton capacity, and foundry buildings have an average age in excess of 20 years, representing a substantial degree of obsolescence, except for those cranes that have been rebuilt.

3. Technology. Iron foundry technology has achieved

substantial and significant progress during the past 25 years in the areas of melting, molding, and coremaking.

At the close of World War II few foundrymen could conceive of widespread melting of iron in anything but the cold or warm blast cupola. Improvements in this area began with the development and acceptance of the hot blast cupola in which the blast air temperature was increased first to 1000° F. and then to temperatures approaching 2000° F. This was followed by the water-cooled hot blast cupola, the use of oxygen enrichment of the blast air, and the replacement of a portion of the coke by hydrocarbons including oil and natural gas.

Concurrent with cupola developments was the development of electric induction furnaces including the coreless furnace used primarily for melting, and the channel induction furnace used occasionally for melting but more often for holding and duplexing. These furnaces, using the relatively more expensive electricity for heat, found early acceptance in areas of plentiful and low cost power. Their popularity increased as coke prices increased and quality decreased. Induction melting received its greatest impetus, however, when two additional factors became widely known: the flexibility permitted by these furnaces to quickly change hot metal analysis, and the lack of emissions resulting from their use. Melting costs were decreased somewhat by the development and use of gas-fired preheaters to raise scrap metal temperatures to the range of 1200°-1400° F.

The acceptance of the concept of electric melting revived interest in the direct arc furnace for melting iron, and

new installations appeared in foundries often in conjunction with preheaters.

The use of electric melting furnaces is not limited to any single size category in the industry. While large and impressive installations have been made in many large production foundries, a far greater number of induction furnaces has been installed in medium and small foundries desirous of benefiting from their flexibility and the savings in emission control equipment.

Melting furnace charge makeup is now computer-assisted in a number of foundries where iron analysis affecting casting quality is critical.

Technological breakthroughs in the molding and core-making areas have been achieved by the development of chemical binders for molding and core sands. Some of the first chemical binders were heat cured while the current research effort is in developing a variety of chemical and catalytic curing agents. An early core binder, still widely used, uses carbon dioxide to cure the binder.

Mechanization of foundries has proceeded at a rapid rate in recent years with more conveyors, instrumentation, and machine controlled functions. The upgrading of machine operators and maintenance personnel has paralleled the advances in equipment design. The development of automatic and flaskless molding machines, core blowers and shooters has decreased the number of semi-skilled workers by their faster cycles and repeatability of mold and core quality.

Foundry technology cannot perhaps compare favorably with many high technology industries such as electronics or computers, but technological developments in the last two decades have increased average foundry productivity by nearly 50%. These improvements are most evident in the medium and large foundries where much of the manual effort has been replaced by machines. Many of the small and very small foundries have changed very little in this time interval. In these foundries molding sand is still prepared for reuse on the foundry floor by workers with a water hose and shovel, finished molds are set out on the floor and filled from a hand ladle, and cupolas are charged manually. It is this type of foundry that will feel most strongly the economic effect of emissions control legislation.

4. Efficiency. Efficiency or productivity of iron foundries can be evaluated in terms of the man-hours of effort required to produce one ton of castings. On this basis different types of iron foundries can be ranked as follows:

Cast Iron Pipe Foundries	8-10 man-hours/ton
Production Foundries	15-30 man-hours/ton
Jobbing Foundries	40-70 man-hours/ton

The current industry average is 23 man-hours/ton reflecting the large tonnage of castings produced by the relatively efficient pipe and high production foundries, particularly the captive automotive foundries.

No general conclusions as to what category of casting producers will be seriously affected by pollution control legislation can be drawn from this consideration alone. Each category

of foundries is necessary to supply the demand for iron castings, and the productivity of each bears a strong correlation to the basic production requirements of its segment of the industry.

Pipe foundries are highly specialized, producing basically a single item in a range of diameters and lengths. Most of these producers make both gray and ductile or malleable iron which does not affect the actual casting of the pipe but only the metal analysis coming from the melting department, plus the addition of a heat treating cycle in the production process for malleable iron. The pipe is produced in centrifugal casting machines. Cores are used only to form the inside surface of the bell end of the pipe. Because of the single product and the high production levels, the foundries are highly mechanized, resulting in a low man-hour input per ton of product.

Production foundries, while producing a greater variety of cast products than pipe foundries, do so in large enough quantities to permit a high degree of mechanization. Separate molding floors are established with manual, semi-automatic or automatic molding machines, sand preparation systems, and conveyors to produce products of similar size, weight, metal analysis, and other characteristics. Production runs of particular castings may be as short as several hours, up to several days, or may even be continuous depending on the quantities required. A single floor may even produce a number of different, but compatible castings simultaneously. Core requirements can vary widely, and most production foundries are equipped with large core rooms, often as mechanized as the molding lines. Productivity is

lower than pipe foundries because of the greater variety and complexity of the work, and because of the need for a greater variety of equipment and skills to satisfy the broader range of castings manufactured.

Jobbing foundries produce the broadest range of casting quantity, size, weight, complexity and material of all three iron foundry categories. The degree of mechanization is usually less for this type of foundry because the variety of castings produced will not generally support the investment in specialized installations. More manual work is therefore required and a lower productivity results.

Each foundry category can be seen to serve a specific industry need. The highly specialized foundry, like the pipe foundries, supplies great quantities of single special products at low cost, the production foundry produces large quantities of parts that can be grouped by their similar characteristics; and the jobbing foundry is equipped to supply small quantities, often only one or two, of a great variety of products but at an understandably higher unit cost.

The quality of management, and, over an extended period of time the financial stability of individual foundries, will differ in all categories and sizes. Financial instability in publicly held foundry companies is more often identified quickly by major stockholders and the problem attacked by management changes. The smaller, family controlled foundry, however, is not infrequently subject to uncorrected management faults. This can result in a steady erosion of the foundry's ability

to produce quality castings and to keep abreast of technological developments involving the purchase of new equipment, due to declining profitability. The small foundry, like all small business, can also be suffering from a lack of working capital and simply not be able to raise the capital required for new equipment. For these and other reasons the smaller foundry is often a marginal operation resulting in its demise in certain circumstances where large expenditures are required to remain in operation.

The small jobbing foundry, whatever the financial pressures may be from time to time, will never completely disappear from the industry. The need for small quantities of a great variety of cast iron products will always exist, and jobbing foundries will also exist to satisfy the demand.

5. Stage in the Production Process. Cast iron pipe foundries and ingot mold foundries are the only major segment of the iron foundry industry completely producing a finished product. With some exceptions cast iron foundries produce an intermediate stage component product which is machine finished and assembled into a finished product by the purchaser.

(f) Iron Foundry Employees and Skills

Exhibit 21 shows the total iron foundry employment for the year 1968 to be 229,812. This figure includes those foundries included in SIC codes 3321 and 3322, and all captive foundries.

The year 1968 is the most recent for which these statistics are available.

Skill levels of foundry labor are tabulated in Exhibit 26. The 18 job classifications have been rated according to NMTA/ NEMA Job Evaluation Plan and encompass a range of 145 to 277.

(g) Significant Trends

Important trends in the iron foundry industry fall into two broad categories, the changes in foundry population and size, and changes in technology. The situation can be described as one in which the small, individually owned entrepreneurships which once characterized the industry are rapidly ceasing to exist, and are being replaced by larger, corporately owned foundries, with an ever-increasing percentage of the latter being captive. The growth of iron castings output, combined with the reduction in number of foundries by 50% in a period of less than 25 years, have resulted in more than double the average output per foundry.

It is particularly significant that the reduction in number of iron foundries has been almost entirely among the small-sized companies. While the medium- and large-sized foundries have remained relatively constant in number, the small foundries have declined to under half of their number during the postwar period. The reasons for this are not difficult to trace. The increasing costs of labor and the greater difficulty in recruiting and holding skilled foundry labor have resulted in a continuing increase in the degree of mechanization in foundries. It was

once possible to operate a foundry on a very small investment in equipment, and to use the same crew to perform all of the functions of melting, molding, pouring, cleaning, etc. The modern foundry requires a high investment cost, with labor being fixed in single area jobs, necessitating relatively continuous operation of the shop.

To all of these problems, the additional consideration of environmental control is now being added. This generally requires the installation of relatively high-cost air, water, noise and other control systems, which further add to the capital and operating costs without, by themselves, contributing to production or earnings. This has caused many marginal operators to go out of business, and can be expected to continue to have this effect in the next decade. An analysis of the iron foundry population in the state of California during the postwar period has shown that the periods when strict enforcement of air pollution codes were introduced were also the periods of most rapid decline in the number of iron foundries.

Despite the reduction in the number of operating foundries over the past years and the projected continuance of that trend through 1980, the industry will continue to meet the demand for iron castings. The average iron castings production per foundry has increased during the last ten years to offset the loss in foundry population, as shown in Exhibit 7, and is projected to increase in the future to 16,000 tons per year in 1980.

There have been major technological improvements in recent years that bear heavily on the industry's ability to continue to meet the increasing demand for iron castings from the ever-decreasing number of foundries. These significant trends in technology are discussed in a later section of this report.

ASSESSMENT OF THE FINANCIAL STRUCTURE TRENDS

(a) Method of Approach

Model data taken from the U.S. Department of Health, Education and Welfare Air Pollution Studies, Number AP-74 were cast into profit and loss and balance sheet form as shown in Exhibit 22 to arrive at and cross verify the data. This data was supplemented by other data provided by the Council on Environmental Quality and was similarly manipulated to accomplish the following:

1. Determine pollution control equipment operating cost as a percent of sales by volume groups.

2. Determine pollution control equipment investment requirements as a percent of total investment by volume groups.

Tests were applied to the averages in three volume groups common to the AP-74 study and the supplmental data to discover the effects on the following:

1. Prices and demand shifts.
2. Sales.
3. Costs, profits and cash flow.
4. Capitalization.

An analysis of the raw data reserved from the I.R.S. through the Council for Environmental Quality indicated that differing capital structures existed between various sizes of foundries. Larger firms seemed to use a higher proportion of suppliers' capital to finance their operations than smaller firms did. The table below (extracted from Exhibit 28) shows this; current liabilities constitute an increasing proportion of total liabilities and net worth as volume groups ascend.

Volume Class (With Controls)	Percent of Total			
	Current Liabilities	Long-Term Debt	Equity	Total Assets or Liabilities and Net Worth
Under $.5 MM	17.9%	3.3%	78.8%	100.0%
$1.0 MM to $2.5 MM	21.2%	4.2%	74.6%	100.0%
$10.0 MM and over	23.7%	1.2%	75.1%	100.0%

It therefore seemed sensible to change the basic measuring base from return-on-investment (defined in the AP-74 study as long-term debt plus equity) to return on total assets (equal, of course, to total liabilities and net worth), thus establishing a common basis for measurement regardless of differing capital structures.

In the process of applying the tests and discovering the effects on the averages, the following assumptions were employed:

1. Measured changes in the above factors if a foundry attempted only to recapture its incremental costs of pollution control devices.

2. Measured changes in the factors if a foundry attempted to restore its pre-pollution control return on total assets rate.

3. Measured changes in the factors if a foundry arbitrarily desired to increase its return on total assets to an average selected 10% rate.

(b) Prices and Demand Shift

Elasticity of demand is dampened in this industry by the following factors:

1) Sales persuasion.

2) Reliable, consistent metallurgy.

3) Purchasing inertia-disinclination to change sources of supply.

4) Patterns owned by casting users are almost always in the hands of the foundry where they are both used and maintained; costs and reluctance to shift to a new source of supply are always associated with "pulling the pattern."

The following pricing phenomenon was calculated based on the data and the assumptions and summarized from Exhibits 29, 30 and 31.

	Price Increase Necessary to		
Volume Group	Cover Costs	Restore R.O.A.	Achieve 10% R.O.A.
Under $0.5 MM	3.94%	5.0%	11.2%
$1.0 MM to $2.5 MM	3.47	5.45	6.7%
Over $10.0 MM	1.44	1.74	4.4%

The following observations might be made from these data:

1. In view of the apparent inelasticity of demand, all price increases in the table above, except for those calling for the foundry to achieve a 10% return on total assets for the

smaller two of the three volume groups, are virtually inconsequential and may cause no demand shift at all.

2. The two larger price increases might possibly cause demand shift on larger orders (arbitrarily $1,000 and over), but such price increases may be countered by price concessions which might easily be made to retain such business and either retard or inhibit any demand shift.

3. The magnitude of the price increases decreases with size as expected because of the smaller proportion of total investment devoted to pollution control devices which a larger foundry would experience compared to a smaller foundry. This positions the larger foundry to acquire business from smaller foundries if it chooses. However, the magnitude of the demand shift is dependent upon a wide variety of factors, including price, which cannot be quantified from the existing data. These factors include, but are not necessarily limited to the following:

- Elasticity of demand as described above.
- Geographical and regional marketing and distribution costs.
- Differing rates at and degrees to which states apply enforcement measures.
- The pace of technology in pollution control devices.
- Foundry specialty and proprietary products.

Taking all of the above factors into consideration to the extent possible, any demand shift should be slight and will do at most nor more than slightly accelerate an existing trend of

demand already shifting from smaller to larger foundries, a phenomenon historically characteristic of many businesses.

(c) Sales

Existing data cannot be used to analyze and assess effects on overall industry sales or even sales of individual foundries except as noted in the section above treating demand shift.

Growth of casting sales is expected to follow past patterns. Effect on the overall sales of the industry from a shift of demand into competitive and substitutable products such as forgings, aluminum castings, fabricated equivalents of castings (weldments), except in pipe where other materials have already made significant inroads, is expected to be small.

(d) Costs, Profits and Cash Flow

The following pollution control costs and effects on pretax profits expressed as a percentage of sales are observable in the table on the following page. Results shown in column four (4) assume no pricing action taken as a result of pollution control installation.

Volume Group	(1) Pollution Control Costs as Percent of Sales	Pre-Tax Profit as Percent of Sales		
		(2) Presently Controlled Foundry	(3) Presently Non-Controlled Foundry	(4) Presently Non-Controlled Foundry After Controls Installed *
Under $.5 MM	3.96%	3.4%	4.9%	0.94%
$1.5 MM to $2.5 MM	3.71	7.2	6.5	2.79
Over $10.0 MM	1.49	7.0	3.3	1.81

Note: *Derived by subtracting column (1) from column (3).

From these data, it appears that:

1. Pollution control equipment costs in aggregate constitute a large proportion of present profits, particularly in the small volume foundries.

2. The presently-non-controlled foundry in the lowest volume group is more profitable than its controlled counterpart and, assuming no price movement, will suffer substantially in profits on installation of pollution control equipment.

3. The presently-non-controlled foundry in the two larger volume groups appears to be at some existing disadvantage profitwise compared to their controlled counterparts. This may be due to management, regional factors, or a wide variety of other factors including statistical ones.

4. Cash flow will, of course, increase markedly, particularly if accelerated depreciation methods are employed, but increased cash flow in and of itself probably would not significantly improve the attractiveness of the investment in pollution control devices.

(e) Capitalization

The following is a comparative table extracted from AP-74 and comparable supplemental data (calculated in the case of the supplemental data).

Volume Group	Pollution Control Investment as Percent of Total Investment	
	AP-74 Study	Supplemental Data
Under $.5 MM	19%	22.1%
$.5 MM to $1 MM	30	NA
$1.0 MM to $2.5 MM	26	29.9
$2.5 MM to $5.0 MM	12	NA
$5.0 MM to $10.0 MM	8	9.6
≥ $10.0 MM	5	NA

The following observations can be made from these data:

1. Supplemental data show costs to be consistently higher than the AP-74 data, but following the same pattern. There are unexplained non-linear steps in the second two volume groups above the lower which have not been resolved.

2. Regardless of the steps in the data, it is obvious that in the $2.5 million dollar volume groups and down, obtaining new investment may be a large barrier to the smaller foundries in acquiring capital for basically a non-productive investment, (defining non-productive in the traditional sense.)

(f) Summary

The following summary observations might be made:

1. Price movements, except in the smaller foundries are not expected to be significant as a result of pollution control installation alone.

2. Price movement, even when significant in smaller foundries, to achieve an adequate return on total assets (10%)

after installing pollution control equipment, may have a negligible effect on shifting demand because of the factors causing demand to be relatively inelastic in the industry.

3. Price increases related to covering pollution control costs probably will not result in widespread substitution.

4. Cost, profits and cash flow, while significantly affected, can be offset by price increases having a negligible effect on demand, and therefore, will not in themselves significantly affect investment decisions to install pollution control devices or alter demand patterns.

5. The magnitude of the investment commitment to a basically non-productive asset, particularly in smaller foundries may constitute a significant barrier. Fast writeoff alone, while benefitting cash flow, may not be sufficient inducement to commit capital to pollution control devices.

6. Existing data is of little value in quantifying demand shift except in a broad general way. Without quantification, few inferences can be drawn as to the effect on employment and business failures.

ASSESSMENT OF CURRENT TECHNOLOGY AND TECHNOLOGICAL TRENDS

Current iron foundry technology has been discussed in some detail earlier in this report. The improvements in melting, charge makeup, and mold and core sand binders have been reported. A quantitative comparison with other industries is difficult,

if not impossible. Qualitatively, foundry technology would lie in the mid-range of the industry spectrum. The casting process is reasonably complex when all factors including pattern making, core and mold making, and metal temperature and analysis exactness are considered. The technology is far below the aerospace industry, however, but above industries like meat packing or the manufacture of metal containers.

The most significant changes in the types and uses of equipment which are expected to take place in the iron foundry are in the melting department. The cupola, which once was almost the only source of molten iron, has been rapidly declining in number of installations, with the number in 1969 being only about 45% of those in existence immediately after the war. This decline has been projected to continue at an undiminished rate, with the number of cupolas in 1980 estimated to be about 1,300. Although part of this decline has been traced directly to the reduction in the number of small-sized foundries, it has also been related to several other factors. The principal one has been the replacement of the cupola by other methods of melting, electric arc, electric induction, and fuel fired reverberatory furnaces. An additional factor has been the replacement, in many foundries, of two or more cupolas by a single, larger-sized unit.

In 1969, an estimated 85% of all iron melted in iron foundries was performed in cupolas. As the replacement of cupolas by other forms of melting continues to accelerate, the amount of

iron melted in cupolas will decrease, with the amount by 1980 projected to be as low as 50% of the total. The electric method of melting, both direct arc and induction, will account for almost 50%, with the small remainder being melted in fuel fired, reverberatory furnaces.

Although the tonnage of malleable iron which is produced has remained relatively constant, the number of reverberatory air furnaces used for duplexing has been declining steadily, as these types of fuel fired furnaces have been replaced by electric furnaces, principally arc furnaces. On the other hand, the tonnage of ductile iron has been increasing every year, and is expected to be about double the 1969 tonnage by 1980. This will result in a corresponding increase in the amount of magnesium treatment of iron which will be performed.

The trend toward mechanization of molding, pouring and shakeout lines has been continuing at an increasing rate. Most of the large- and medium-sized foundries employ some degree of mechanized molding. With the development of dependable and economical automated molding systems for small-sized molds, many of the small foundries have installed mechanized lines. Similarly, there is an increasing number of foundries in which continuous and automated sand handling and preparation systems have been installed. There is every reason to believe that within the next 10 years, the majority of iron foundries will use some form of mechanized molding, pouring, shakeout and sand preparation.

Coremaking has also been undergoing a technological change with the trend being away from oil-bonded, baked sand cores toward chemically bonded, thermally cured and air cured cores. Core processing is becoming mechanized and automated. Fuel fired core ovens are being replaced with dielectric ovens, or with processes in which cores are cured directly in the core boxes.

The entire area of handling and preparation of materials used in the foundry is continually being reviewed with respect to the effect on emissions production and economy of collection. Iron foundries are being more selective in purchasing of scrap, with more attention being given to elimination of combustible materials from the scrap before purchase. Larger foundries are installing scrap preparation facilities involving pre-burning or cleaning to remove materials which will produce emissions during melting. Screening of coke and stone, and use of higher quality briquettes are recognized as a means of eliminating fines which will tend to blow out of furnaces during melting.

It is believed that the next generation will see an increasing trend toward centralized scrap preparation yards which will service many iron foundries in a given area. This will help to provide cleaner scrap at lower costs.

Many of the trends toward electric or fuel fired melting furnaces, mechanized molding, and continuous sand preparation systems will have important effects in reducing the quantity of

emissions produced, or in making the emissions easier or less costly to collect. The decisions made in selecting new equipment are, therefore, being made to an increasing degree with reference to the effect on reduction of emissions, or on economy of emissions collection.

The use of a greater amount of pre-cleaned or burned scrap will reduce the quantity of emissions from combustibles now charged into furnaces along with the scrap. Screening to remove fines will also help to accomplish this same goal.

The trend away from cupola melting and toward electric or fuel fired melting furnaces will have a significant effect in reducing emissions. The electric induction furnaces and the fuel fired reverberatory furnaces produce a very small quantity of emissions. The electric arc furnace emissions are substantial in quantity, but are much easier and more economical to collect than are cupola emissions.

The mechanization of molding, pouring, shakeout and sand preparation facilities has not reduced the quantities of emissions which are produced, but has resulted in confining their production to fixed locations. Thus, it is relatively simple in many cases to construct enclosures which can be used as a means of collection of emissions with a minimum of infiltrated air. This not only reduces the size and cost of the collection system, but makes it more effective, reducing the amount of unconfined emissions which are released in the foundry building.

ASSESSMENT OF CURRENT CAPACITY

The total industry productive capacity in terms of weight of good castings can be closely estimated by considering the total simultaneous melting capacity and the average yield of good castings from hot metal. Total melting capacity does not equate to total installed capacity. Many foundries have two cupolas connected to a single air supply system and/or emission control system permitting operation of the furnaces on alternate days. Similarly, some foundries using induction melting furnaces provide a spare furnace for every four to six operating furnaces. Exhibit 21 shows the following statistics:

Furnace Type	Number in Operation	Total Melting Capacity-Tons/ Hours
Cupola	1,915	18,570
Arc Furnace	374	2,789
Induction Furnace	-	564
		21,923

This total net hourly melting capacity represents an annual industry melting capacity of 43,846,000 tons based on 2,000 operating hours per year. The average industry yield of good castings to molten iron is approximately 73%, resulting in a total annual capacity of slightly over 32 million tons of good castings. This substantial overcapacity is accounted for in part by the fact that many small foundries operate their furnaces four to six hours per day, two on three days a week. On the alternate days molds are made and set out on the floor for

pouring when hot metal becomes available. While operating methods would require changing to provide sufficient molds for daily furnace operation, this would not be extremely difficult. The overcapacity, of course, also indicates the strong competitive condition existing in the industry.

ASSESSMENT OF CURRENT COMPETITION

The competitive position of iron castings must be examined on three levels as follows:

(1) Competition between cast iron and other materials and manufacturing processes.

(2) Competition between U.S. producers of iron castings.

(3) Competition between U.S. and foreign producers of iron castings.

The competitive situation between iron castings and other materials has been discussed at some length earlier in this report, and can be summarized as follows. Cast iron has some desirable physical and chemical properties that limit competition for many products. Steel weldments can often be substituted for iron castings and are sometimes less expensive if the quantities required are small. For large lots of complicated castings permitting the economic amortization of expensive patterns, iron castings are usually less costly. Steel forgings can be substituted for malleable iron but usually at a higher cost. Some large machinery bases and frames, traditionally made from cast iron are now being manufactured of welded steel plate, at a savings in weight

for approximately competitive prices. The weight savings can be a consideration when the products are to be shipped long distances. Many foreign-made machine tools are fabricated in this manner. These products are considered by many purchasers to be less satisfactory since steel does not have the vibration and shock dampening property of cast iron. Exhibit 32 shows average prices per ton for cast iron products.

The major segment of the industry affected by competitive pressures of other products is cast iron pressure and soil pipe. The relative usage of iron pipe and competing products is shown in Exhibit 33, and relative costs per foot of these products are tabulated in Exhibit 34. For use as pressure pipe, plastic, concrete and asbestos-cement pipe are substantially lower in price than cast iron, including both material and installation costs. In the soil pipe product line vitrified clay, concrete, asbestos-cement, and bituminous fiber pipe products are also substantially less costly than cast iron. These other materials provide severe competition for cast iron and some outsell iron pipe in certain types of service as shown in Exhibit 33. The difference in installed cost is so large in many cases that the competitive position will be affected in only a minor way by a 5% increase in cast iron as the result of air pollution control costs. It would appear unlikely that a noticeable shift in usage would result.

Current competition between foundries exists to any significant degree only between foundries in the same classification, such as jobbing, production, and specialty foundries. Competition

is also limited geographically since shipping costs can easily erase the FOB unit cost differential if the product is to be shipped more than 100-200 miles. Large production foundries are geared for large production lots and generally cannot compete with the small foundry capable of producing small orders. Competition is also somewhat limited by the pattern equipment not always easily transferrable to different molding machines owned by another foundry, and because the patterns are sometimes owned by the casting manufacturer.

The small profit margin on iron castings is due in part to normal competitive pressures and current economic conditions. A minimum of potential for price adjustments exists in the industry. The complexity of the process and the resulting problems of producing a product meeting specifications often result in quality being a prime factor in obtaining business.

Competition from foreign castings producers has not been strong until recent years. Recently, however, it has been growing, particularly from low income countries such as Japan. This competition is expected to grow in the coming years and will become a large factor unless pressures in and outside the industry are successful in controlling imports.

GOVERNMENT INFLUENCE ON CASTING SUPPLY

No appreciable government influence has been identified on casting supply. Subsidies and quotas have not been applied to iron

castings directly. Such influence, where it exists, on products containing iron castings as components must affect industry production, but are not easily identifiable on an industry basis.

SHIPMENTS OF IRON FOUNDRY PRODUCTS, TONS AND PERCENT

Iron Foundry Product	1970 Tons x 1,000	1969 Tons x 1,000	1968 Tons x 1,000	1967 Tons x 1,000	1966 Tons x 1,000	1965 Tons x 1,000	1964 Tons x 1,000	1963 Tons x 1,000	1962 Tons x 1,000	1961 Tons x 1,000	1960 Tons x 1,000
Gray and Ductile Iron Foundry Products											
Molds for Heavy Steel Ingots	1,472(1)	1,835(1)	1,629(1)	1,341(1)	1,570(1)	1,606(1)	1,407(1)	1,133(1)	1,043(1)	1,092(1)	1,120(1)
Cast Iron Pressure Pipe	1,915	1,811	1,854	1,780	1,805	1,876	1,859	1,677	1,351	1,384	1,336
Cast Iron Soil Pipe	955	1,020	1,084	939	986	958	960	913	888	834	782
Miscellaneous Castings	7,678	9,141	8,703	8,429	9,515	9,472	8,422	7,799	7,226	6,450	7,229
Total Gray and Ductile	12,020	13,807	13,190	12,489	13,876	13,912	12,628	11,522	10,508	9,760	10,467
Malleable Iron Foundry Products											
Standard	627	795	715	751	850	827	736	691	643	554	632
Pearlitic	226	377	292	290	281	309	265	242	225	169	189
Total Malleable	853	1,172	1,007	1,041	1,131	1,136	1,001	933	868	723	821
Total Iron	12,873	14,979	14,197	13,530	15,007	15,048	13,629	12,455	11,376	10,483	11,288

Iron Foundry Product	1970 Percent	1969 Percent	1968 Percent	1967 Percent	1966 Percent	1965 Percent	1964 Percent	1963 Percent	1962 Percent	1961 Percent	1960 Percent
Gray and Ductile Iron Foundry Products											
Molds for Heavy Steel Ingots	11.4%	12.2%	11.5%	9.9%	10.5%	10.7%	10.3%	9.1%	9.2%	10.4%	9.9%
Cast Iron Pressure Pipe	14.9	12.1	13.1	13.2	12.0	12.5	13.6	13.5	11.9	13.2	11.8
Cast Iron Soil Pipe	7.4	6.8	7.1	6.9	6.6	6.4	6.9	7.3	7.8	8.0	6.9
Miscellaneous Castings	59.6	61.0	61.3	62.3	63.4	62.9	61.8	62.6	63.5	61.5	64.1
Total Gray and Ductile	93.3%	92.1%	93.0%	92.3%	92.5%	92.5%	92.6	92.5%	92.4%	93.1%	92.7%
Malleable Iron Foundry Products	6.7%	7.9%	7.0%	7.7%	7.5%	7.5%	7.4	7.5%	7.6%	6.9%	7.3%
Total Iron	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

Note: (1) Direct iron from blast furnaces excluded from reported figures.

Source: U.S. Department of Commerce, Bureau of the Census, Current Industrial Reports, adjusted to exclude direct iron normally reported with molds for heavy steel ingots.

EXHIBIT I

EXHIBIT 2

DISTRIBUTION OF MISCELLANEOUS IRON CASTINGS, 1967(1)

SIC Code	Industry User	1967 Distribution Tons x 1,000	1967 Distribution Percent	Approximate 1970 Distribution-Tons x 1,000
3717	Motor Vehicle Parts and Accessories	2,593	27.4%	2,338
3522	Farm Machinery	558	5.9	503
3711	Motor Vehicles	505	5.3	452
3519	Internal Combustion Engines	295	3.1	264
3531	Construction Machinery	247	2.6	222
34310	Enameled Sanitary Ware	207(2)	2.2	188
3433	Heating Equipment	199(2)	2.1	179
3494	Valves and Pipe Fittings	165	1.7	145
3541	Metal Cutting Machine Tools	160	1.7	145
3561	Pumps and Compressors	144	1.5	128
33214	Cooking Utensils	140(2)	1.5	128
3585	Refrigeration Machinery	132	1.4	119
3566	Power Transmission Equipment	106	1.1	94
3742	Railroad and Street Cars	104	1.1	94
3621	Motors and Generators	91	1.0	85
3599	Miscellaneous Machinery except Electrical	75	0.8	68
3555	Printing Trades Machinery	67	0.7	60
3429	Hardware, n.e.c.	55	0.6	51
3552	Textile Machinery	55	0.6	51
3531	Industrial Trucks and Tractors	51	0.5	43
3633	Household Laundry Equipment	47	0.5	43
3559	Special Industry Machinery	44	0.5	43
3542	Machine Tools-Metal Forming	44	0.5	43
3544	Special Dies, Tools, Jigs and Fixtures	40	0.4	34
3554	Paper Industries Machinery	29	0.3	26
3562	Ball and Roller Bearings	24	0.3	26
3569	General Industrial Machinery, n.e.c.	22	0.2	17
3551	Food Products Machinery	20	0.2	17
3553	Woodworking Machinery	20	0.2	17
3548	Metalworking Machinery, n.e.c.	19	0.2	17
	All Other	3,212	33.9	2,891
	Total	9,470	100.0%	8,531

n.e.c.: Not elsewhere classified.

Notes: (1) Does not include cast iron pipe or ingot molds.

(2) 1965 data.

(3) Department of Commerce, Bureau of the Census, 1967 Census of Manufactures.

EXHIBIT 3

IRON FOUNDRY CASTING PRODUCTION BY COUNTRY

Country	Estimated(1) Number of Total Foundries	Iron Casting Production Metric Tons(2)
Western Europe		
Austria	100	213,800
Belgium (1964)	230	369,100
Denmark	350	139,200
Finland	250	104,800
France	2,400	2,198,600
West Germany	3,000	4,116,600
Great Britain	2,400	4,149,000
Italy	1,400	960,000
Luxembourg	200	64,000
Netherlands	300	245,000
Norway	300	115,000(e)
Portugal (1964)	200	63,500
Spain (1964)	400	695,000
Sweden	500	550,000
Switzerland	300	199,000
Eastern Europe		
Czechoslovakia	n.a.	1,500,000(e)
East Germany	n.a.	1,100,000(e)
Hungary	n.a.	287,000
Poland	n.a.	1,244,000
Romania	n.a.	386,000
Yugoslavia	n.a.	200,000(e)
U.S.S.R.	5,000	14,000,000(e)
Other Countries		
India	4,500	1,964,400
Japan	4,000	3,062,000
South Africa (1966)	1,500	292,400
Mexico	500	n.a.
Canada	453	587,000
U.S.A.		12.9×10^6 Short Tons

Notes: (1) Includes steel and nonferrous foundries.

(2) Based on 1965 data unless otherwise noted.

(e) = Estimated.
n.a.= No figures available.

Source: Marketing Guide to the Metal Casting Industry, Penton Publishing Co.

EXHIBIT 4

U.S. CAST IRON IMPORTS BY COUNTRY OF ORIGIN, JANUARY, 1968 TO APRIL, 1968

	Pig Iron Including Cast Iron ($ x 1,000)	Cast Iron Pipes and Tubes ($ x 1,000)	Iron Castings in the Rough State ($ x 1,000)	Cast Iron Fittings ($ x 1,000)
Canada	2,006	7	493	1,403
Brazil	976	60		
Sweden	487			
Finland	72			
United Kingdom	798		125	77
Netherlands	708	23		
West Germany	609	37	132	
Spain	345			
France		376	10	8
India		188		26
Australia		19		
Mexico			44	46
Belgium			7	
Japan			391	1,176
Republic South Africa			60	
Poland				58
Israel				12
Other Countries		7	13	6
Period Total	6,001	717	1,275	2,834

Source: U.S. Department of Commerce, Bureau of the Census, U.S. Imports, May 1968.

EXHIBIT 5

SUMMARY OF U.S. IMPORTS AND EXPORTS * OF IRON FOUNDRY PRODUCTS, (3321 AND 3322)

Year	Imports(1) ($ Millions)	Exports ($ Millions)
1961	4.6	12.3(2)
1962	6.5	13.0(2)
1963	7.3	25.7(2)
1964	6.5	20.8(2)
1965	5.8	29.6
1966	5.7	37.5
1967	5.8	37.6

Notes: (1) Does not include molds for heavy steel ingots.

(2) Does not include cast iron rolls for rolling mills.

* Assumed to include only castings in the rough state.

Source: Department of Commerce, Bureau of the Census, U.S. Commodity Exports and Imports As Related to Output, 1967 and 1966.

EXHIBIT 6

U.S. IMPORTS AND EXPORTS OF IRON FOUNDRY COMMODITIES, 1968

Import Commodity	January to April, 1968 (Tons x 1,000)	January to(1) April, 1968 ($ x 1,000)	Annual Imports Projected ($ x 1,000)
Pig Iron Including Cast Iron	178.4	6,001	24,004
Cast Iron Pipes and Tubes	7.4	717	2,868
Iron Castings in the Rough State	3.4	1,275	5,100
Cast Iron Fittings, Not Malleable	3.4	996	3,984
Cast Iron Fittings, Malleable	5.0	1,838	7,352
Total	197.6	10,827(4)	43,308(4)

Export Commodity	January to April, 1968 (Tons x 1,000)	January to(2) April, 1968 ($ x 1,000)	Annual Exports Projected ($ x 1,000)
Pig Iron Including Cast Iron	3.8	226	904
Cast Iron Pressure Pipe	8.6	1,841	7,364
Cast Iron Soil Pipe	7.1	1,340	5,360
Malleable Iron Fittings	.5	680	2,720
Gray Iron Castings in the Rough State	18.3	6,877	27,508
Malleable Iron Castings in the Rough State	6.7	2,166	8,664
Total	45.0	13,130(5)	52,520(5)

Value of U.S. Shipments, 1968 (Shown for Comparison) $3,378.9 Million(3)

Notes: (1) U.S. Department of Commerce, Bureau of the Census, U.S. Imports, May 1968.

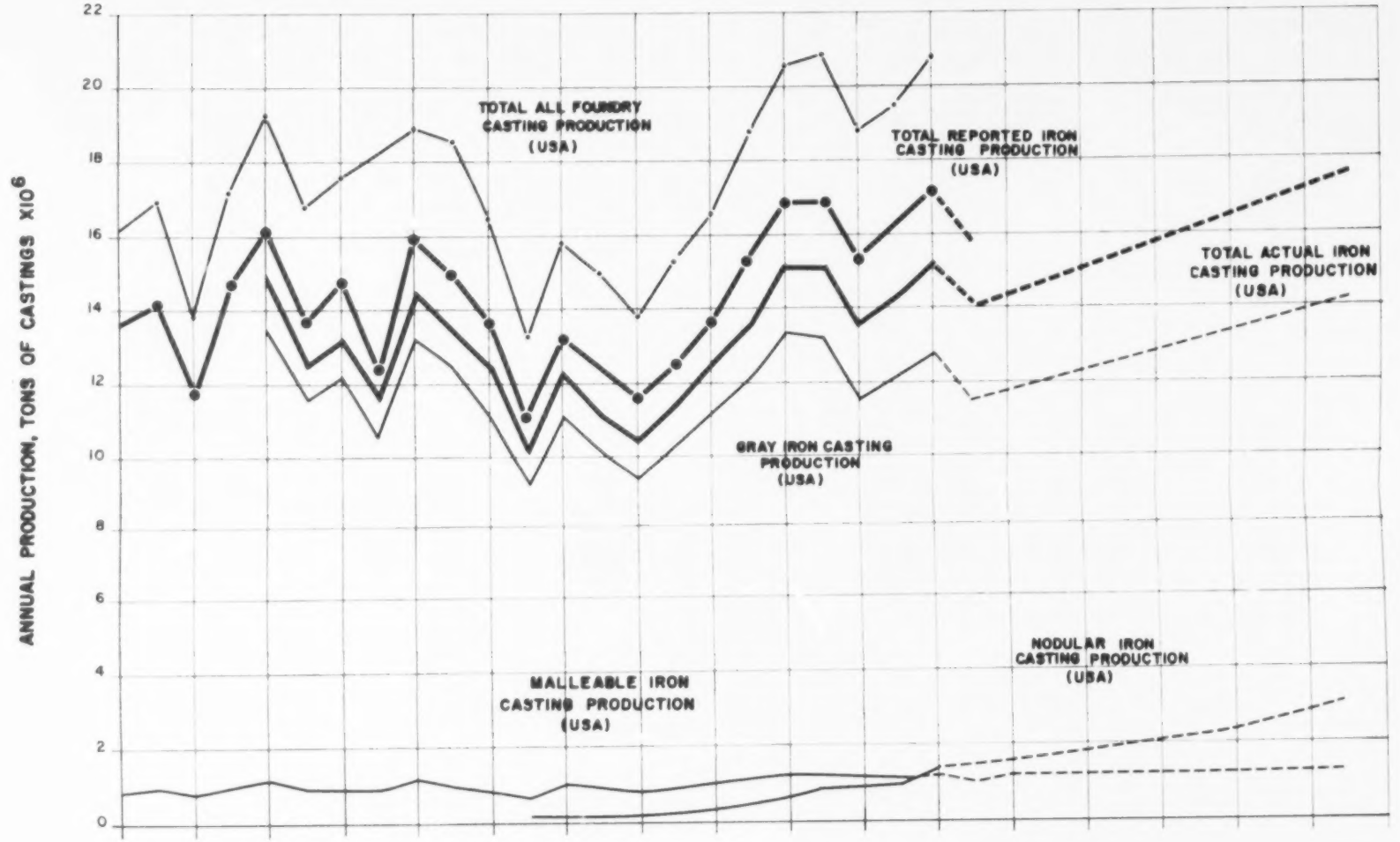
(2) U.S. Department of Commerce, Bureau of the Census, U.S. Exports, May 1968.

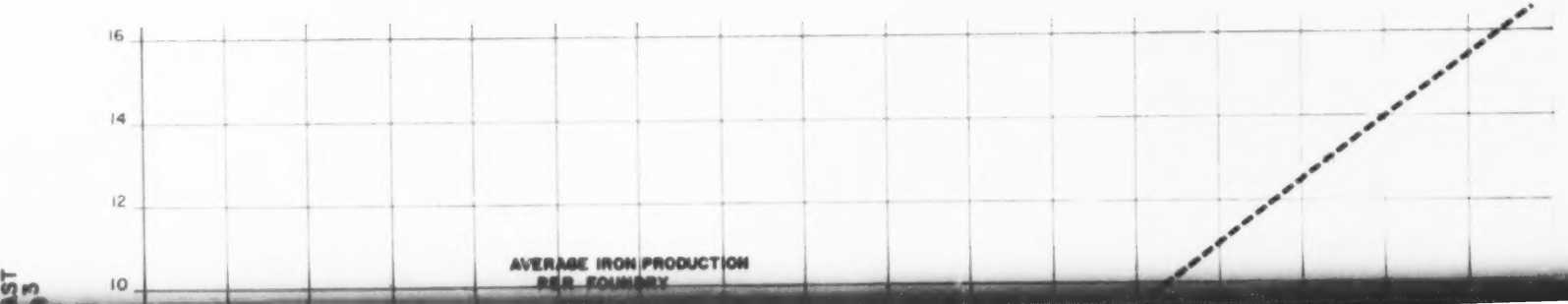
(3) U.S. Department of Commerce, Industry Profiles 1958-1968.

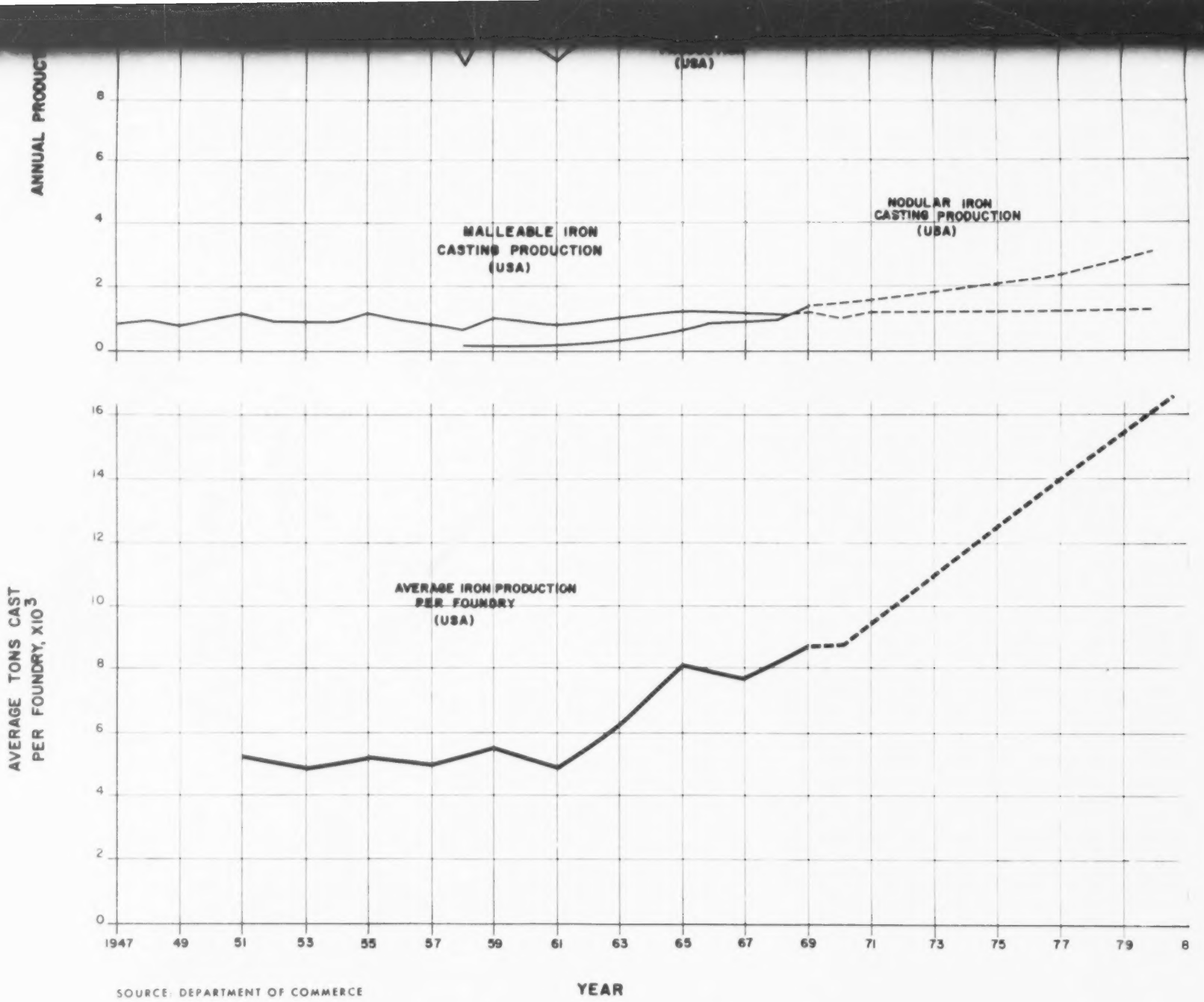
(4) Does not include import duties, freight or insurance.

(5) Includes freight, insurance and other charges to point of exportation.

IRON FOUNDRY PRODUCTION TRENDS

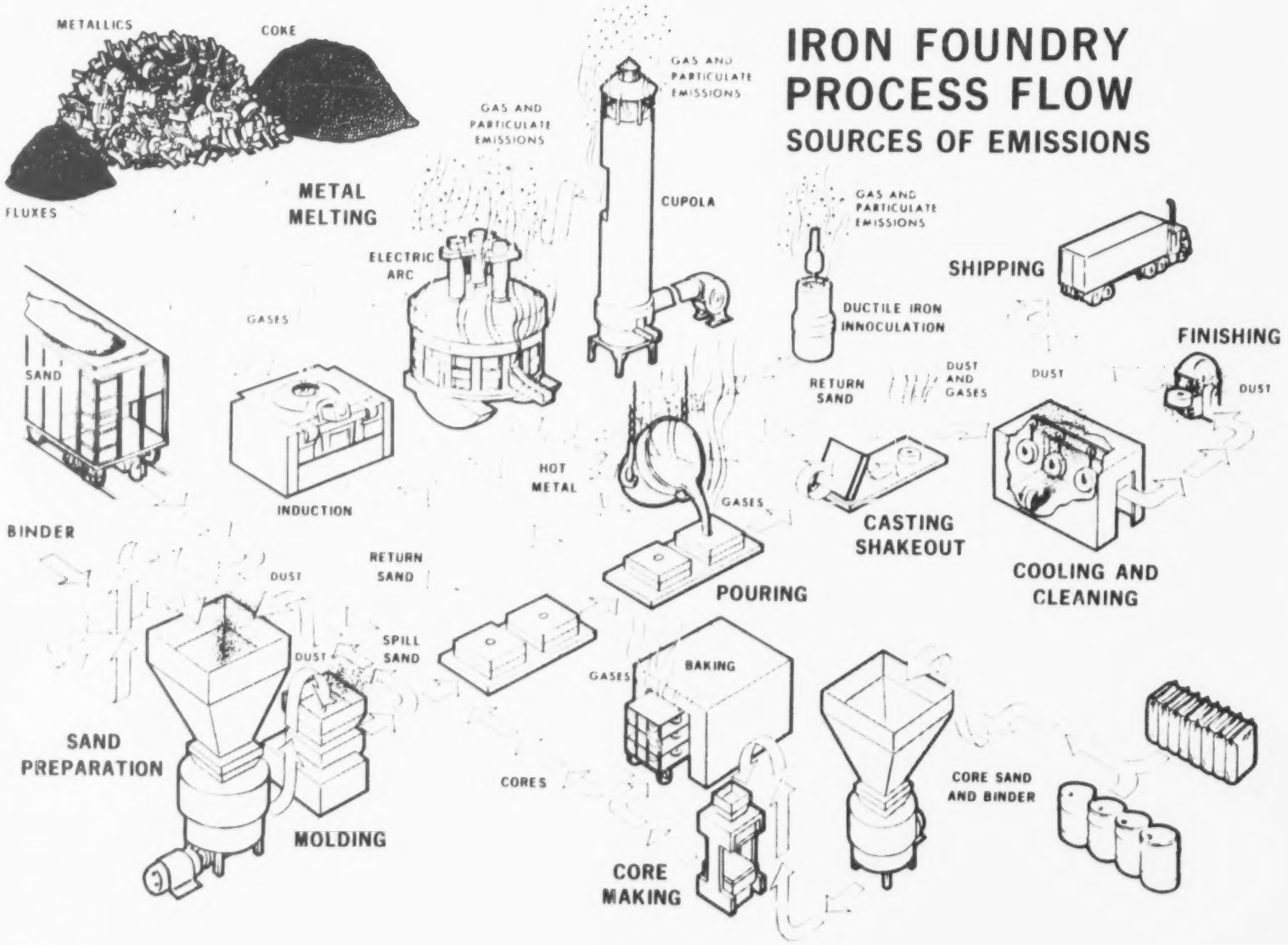






SOURCE: DEPARTMENT OF COMMERCE

EXHIBIT 7


IRON FOUNDRY
PROCESS FLOW
SOURCES OF EMISSIONS
METALLICS
COKE
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METAL
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GAS AND
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CUPOLA
ELECTRIC
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GASES
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INDUCTION
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METAL
GAS AND
PARTICULATE
EMISSIONS
SHIPPING
DUCTILE IRON
INNOCULATION
FINISHING
RETURN
SAND
DUST
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GASES
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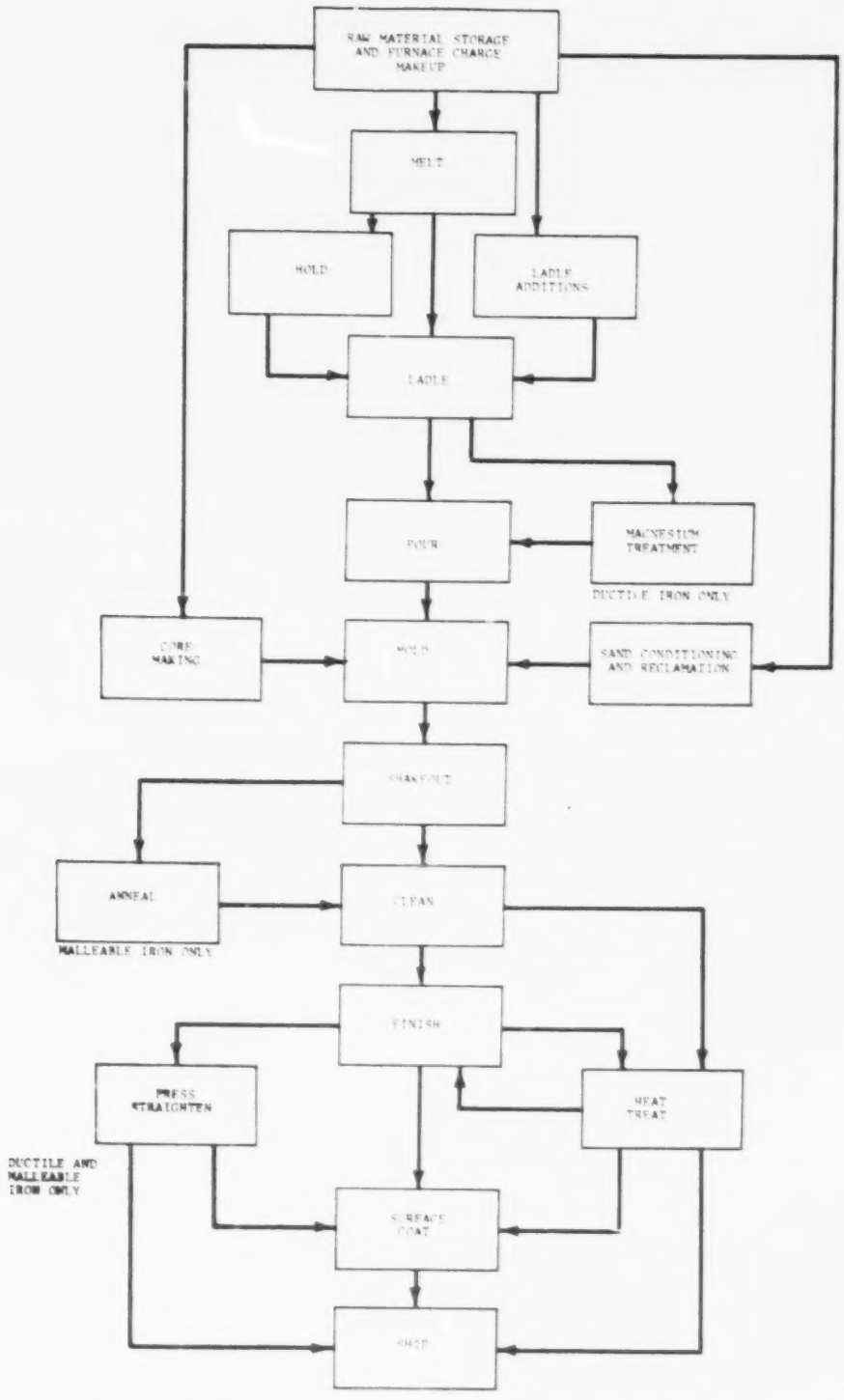
DUST
CASTING
SHAKEOUT
COOLING AND
CLEANING
GASES
POURING
RETURN
SAND
DUST
SPILL
SAND
DUST
BAKING
GASES
SAND
PREPARATION
MOLDING
CORES
CORE SAND
AND BINDER
CORE
MAKING

EXHIBIT 8

EXHIBIT 9

PROCESS FLOW DIAGRAM

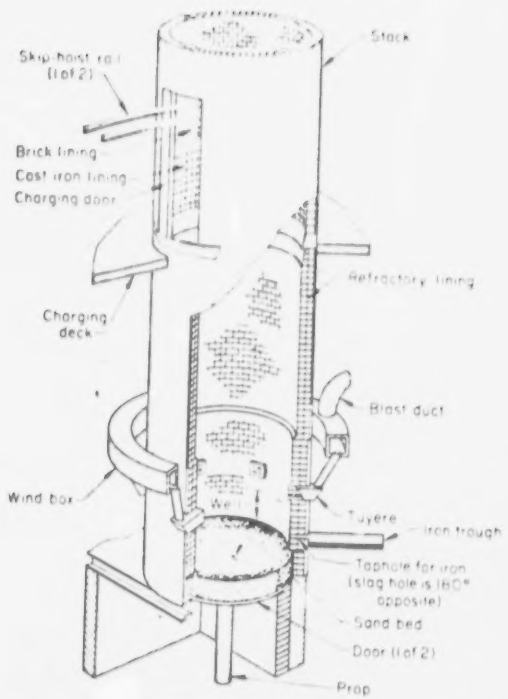
GRAY, DUCTILE AND MALLEABLE IRON



NOTE: ALL OPERATIONS APPLY TO GRAY, DUCTILE AND MALLEABLE IRON UNLESS OTHERWISE NOTED.

EXHIBIT 10

ILLUSTRATION OF CONVENTIONAL LINED CUPOLA

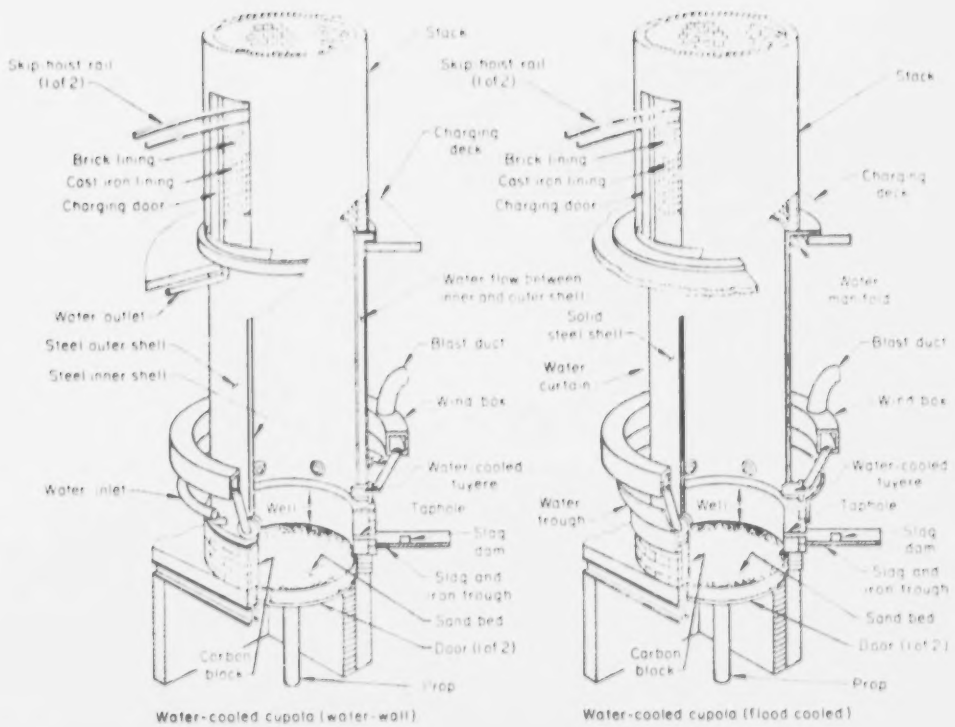


Conventional cupola

Source: Metals Handbook, 8th Edition, Vol. 5, Forging and Casting, American Society for Metals, 1970, p. 337.

EXHIBIT 11

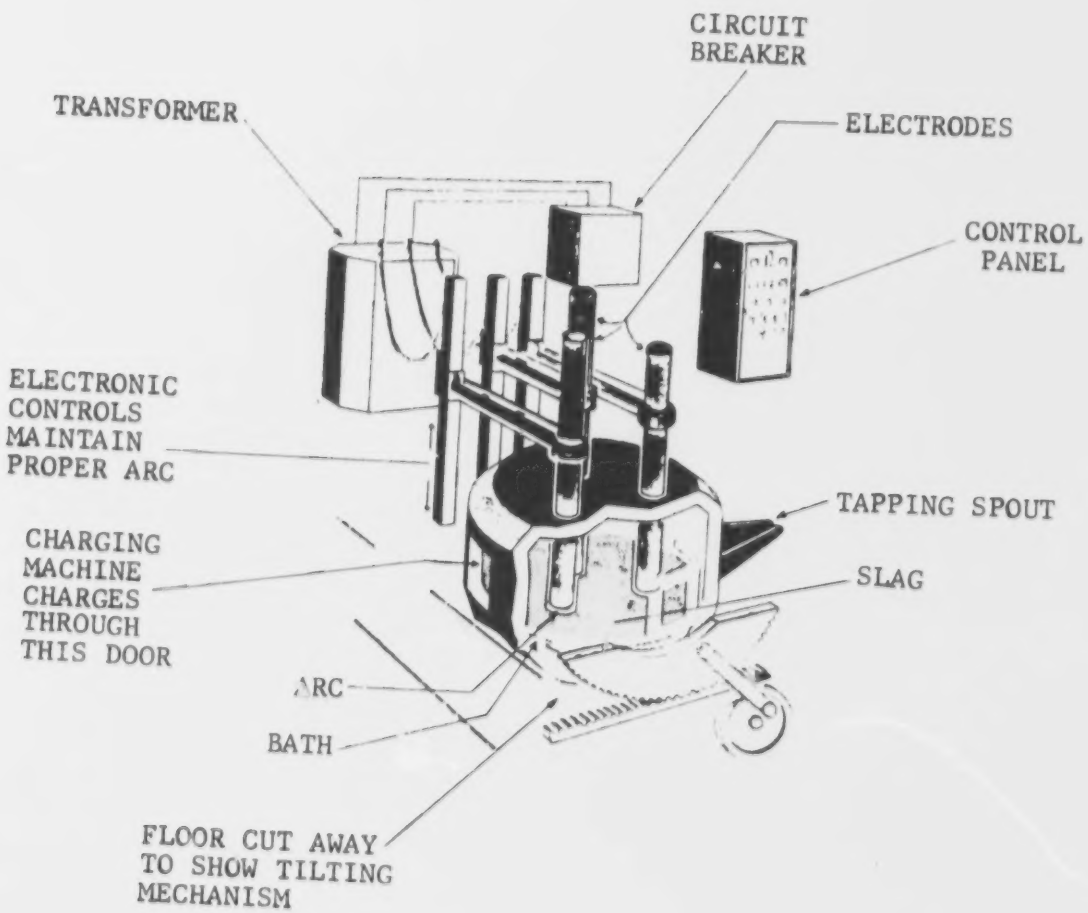
ILLUSTRATION OF WATER-COOLED CUPOLA



Source: Metals Handbook, 8th Edition, Vol. 5, Forging and Casting, American Society for Metals, 1970, p. 337.

EXHIBIT 12

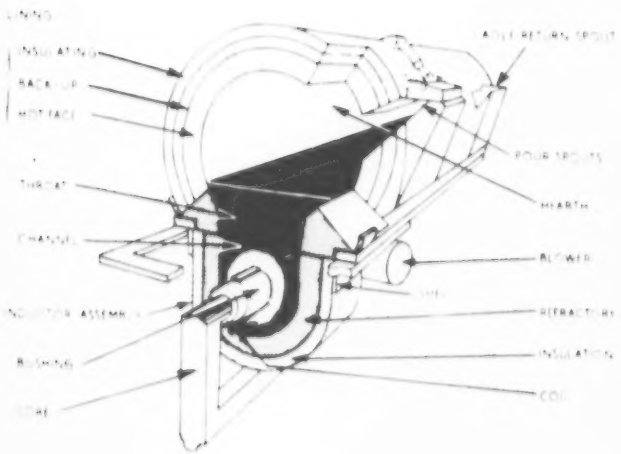
ILLUSTRATION OF ELECTRIC ARC FURNACE



Source: The Picture Story of Steel, published by the American Iron and Steel Institute, 1952, p. 18.

EXHIBIT 13

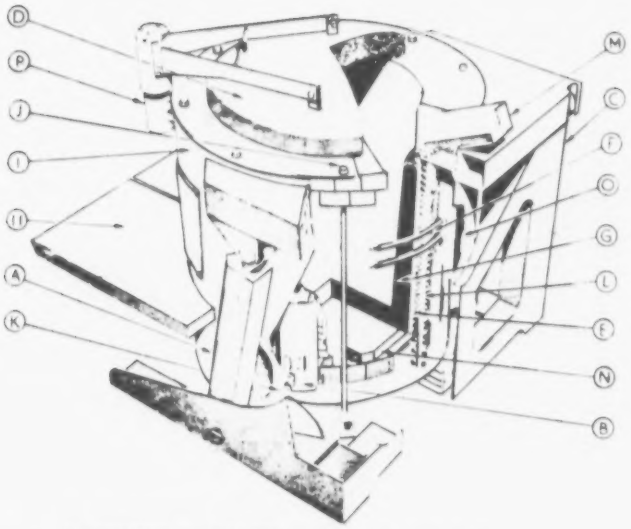
ILLUSTRATION OF CHANNEL INDUCTION FURNACE



Source: "Electric Melting for Mass Production in U.S. Iron Foundries," Modern Casting, July, 1968, p. 47.

EXHIBIT 14

ILLUSTRATION OF CORELESS INDUCTION FURNACE

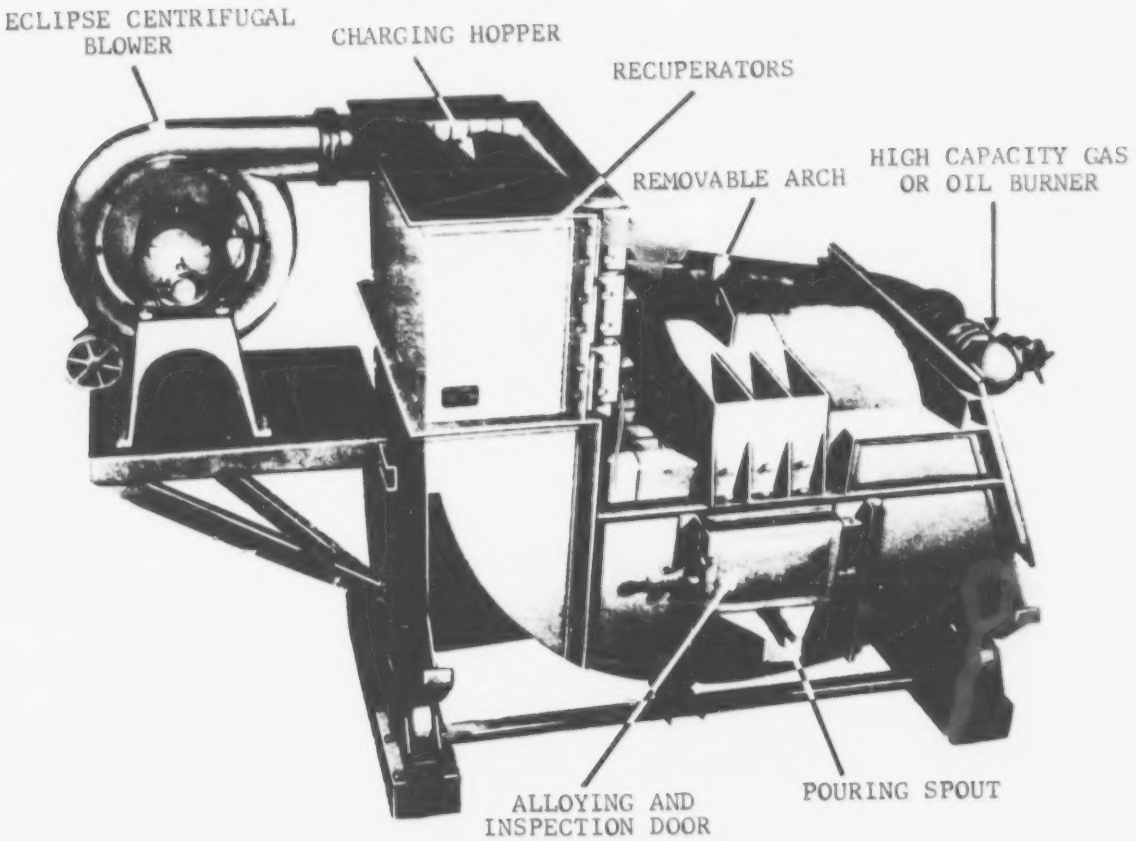


A. HYDRAULIC TILT CYLINDERS
B. SHUNTS
C. STANCHION
D. COVER
E. COIL
F. LEADS
G. WORKING REFRACTORY
H. OPERATOR'S PLATFORM
I. STEEL SHELL
J. TIE RODS
K. CLAMPING BOLTS
L. COIL SUPPORT
M. SPOUT
N. REFRACTORY BRICK
O. ACCESS PORT
P. LID HOIST MECHANISM

Source: "Electric Melting for Mass Production in U.S. Iron Foundries," Modern Casting, July, 1968, p. 47.

EXHIBIT 15

ILLUSTRATION OF REVERBERATORY FURNACE



Source: Eclipse Fuel Engineering Company.

EXHIBIT 16

LOCATION OF PRINCIPAL SUPPLIERS OF FOUNDRY COKE AND PIG IRON

Location		Coke	Pig Iron and Silvery Iron
Alabama:	Birmingham	X	X
California:	Los Angeles	X	X
Colorado:	Pueblo	X	X
Illinois:	Chicago	X	X
Iowa:	Keokuk		X
Indiana:	Indianapolis	X	
	Terre Haute	X	
Michigan:	Detroit	X	
Minnesota:	St. Paul	X	
Missouri:	St. Louis	X	
New York:	Buffalo	X	X
	North Tonowanda		X
Ohio:	Cleveland		X
	Ironton	X	
	Painesville	X	
	Toledo		X
	Youngstown		X
Pennsylvania:	Erie	X	
	Philadelphia	X	
	Pittsburgh	X	X
	Sharpsville		X
	Swedeland	X	
Tennessee:	Chattanooga	X	
Utah:	Geneva	X	X
Wisconsin:	Milwaukee	X	

Source: Foundry Magazine.

MATERIALS CONSUMED, BY KIND,
IN IRON FOUNDRIES
(SIC 3321 PLUS 3322)

Material	1967 Quantity (Tons x 1,000)	1967 Delivered Cost ($ Millions)	1963 Quantity (Tons x 1,000)	1963 Delivered Cost ($ Millions)
Pig Iron (excluding silvery iron)	3,485.6	201.5	4,498.4	283
Nonferrous metals, alloys:				
Aluminum, unalloyed Aluminum, base alloys	4.0(1)	2.0(1)	12.2	5.3
Copper, unalloyed Copper-base alloy raw materials	3.9(1)	3.9(1)	9.6	5.4
Zinc and zinc-base alloys	0.8(1)	0.2(1)	0.7	0.1
Magnesium and magnesium-base alloys	11.1(1)	5.8(1)	9.9	4.9
Ferromanganese	20.7	3.3	25.9	3.9
Other ferroalloys, including silvery iron	344.5	51.6	343.9	44.3
Purchased Scrap:				
Iron and steel	7,105.7	233.8	5,897.5	194.6
Aluminum and aluminum-base alloy	(1)	(1)	(D)	(D)
Copper and copper-base alloy	2.2(1)	1.6(1)	1.2(1)	0.6(1)
Sand	3,907.6	25.2		
Clay refractories	34.3	8.4	(X)	217.3
Nonclay refractories	(NA)	4.9		
All other materials and components (excluding coal and coke)	(X)	477.3		
Total Materials	(X)	1,019.2	(X)	759.4
Coal	321.2	3.7		
Coke	1,312.9	47.1		
Fuel Oil (1,000 barrels)	578.6	2.4	(X)	67.3
Gas (mil. cu. ft.)	34,600.4	18.3		
Other Fuels	(X)	11.9		
Purch. Electric Energy (mil. kw. hrs.)	3,584.6	39.7	2,237.0	27.0
Total Fuel and Energy	(X)	123.1	(X)	94.3

Notes: (1) Estimates.

(D) Withheld to avoid disclosing figures for individual companies.

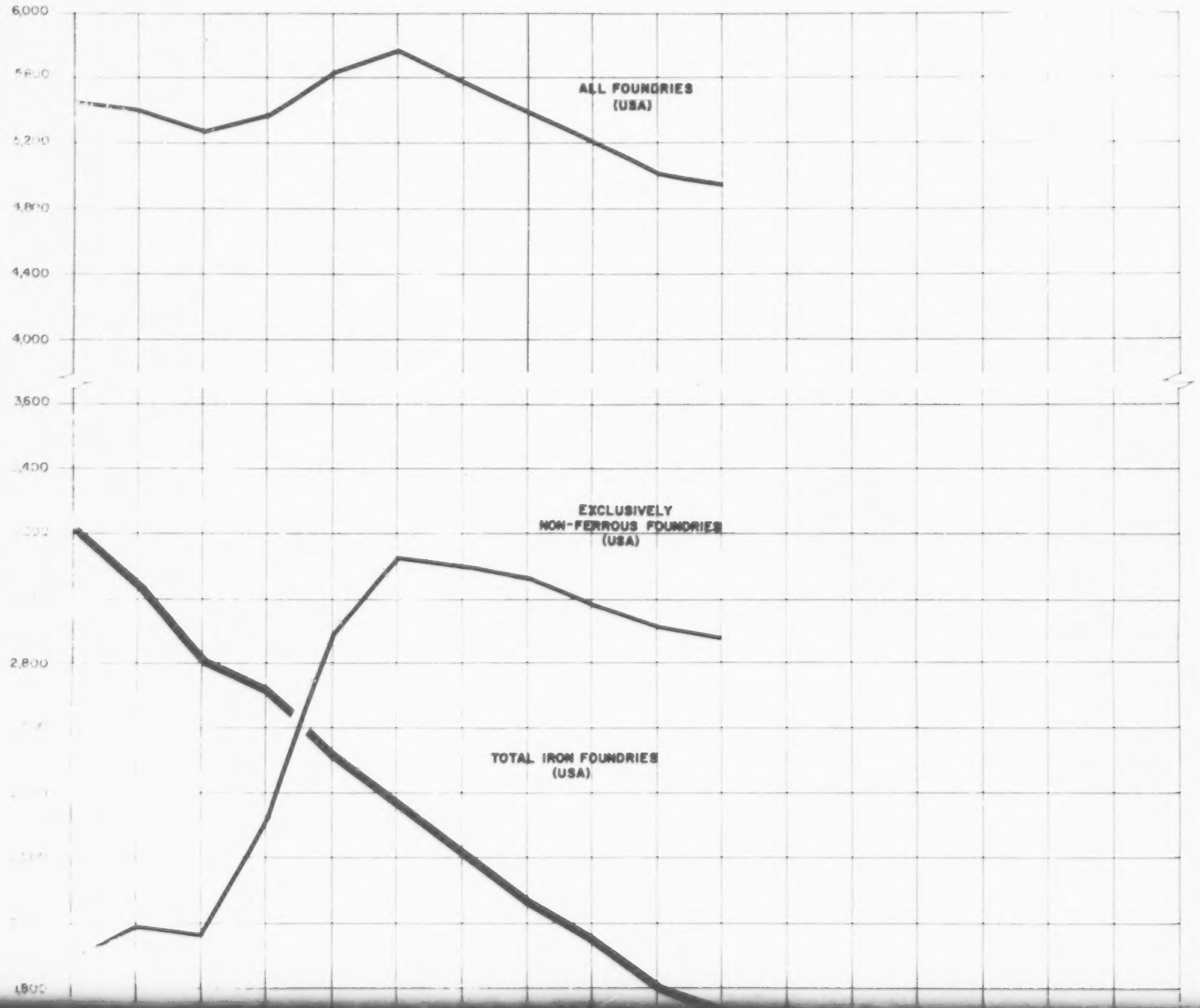
(NA) Not Available.

(X) Not Applicable.

Source: U.S. Department of Commerce, Bureau of the Census, Census of Manufactures.

EXHIBIT 17

POPULATION TRENDS IN THE FOUNDRY INDUSTRY



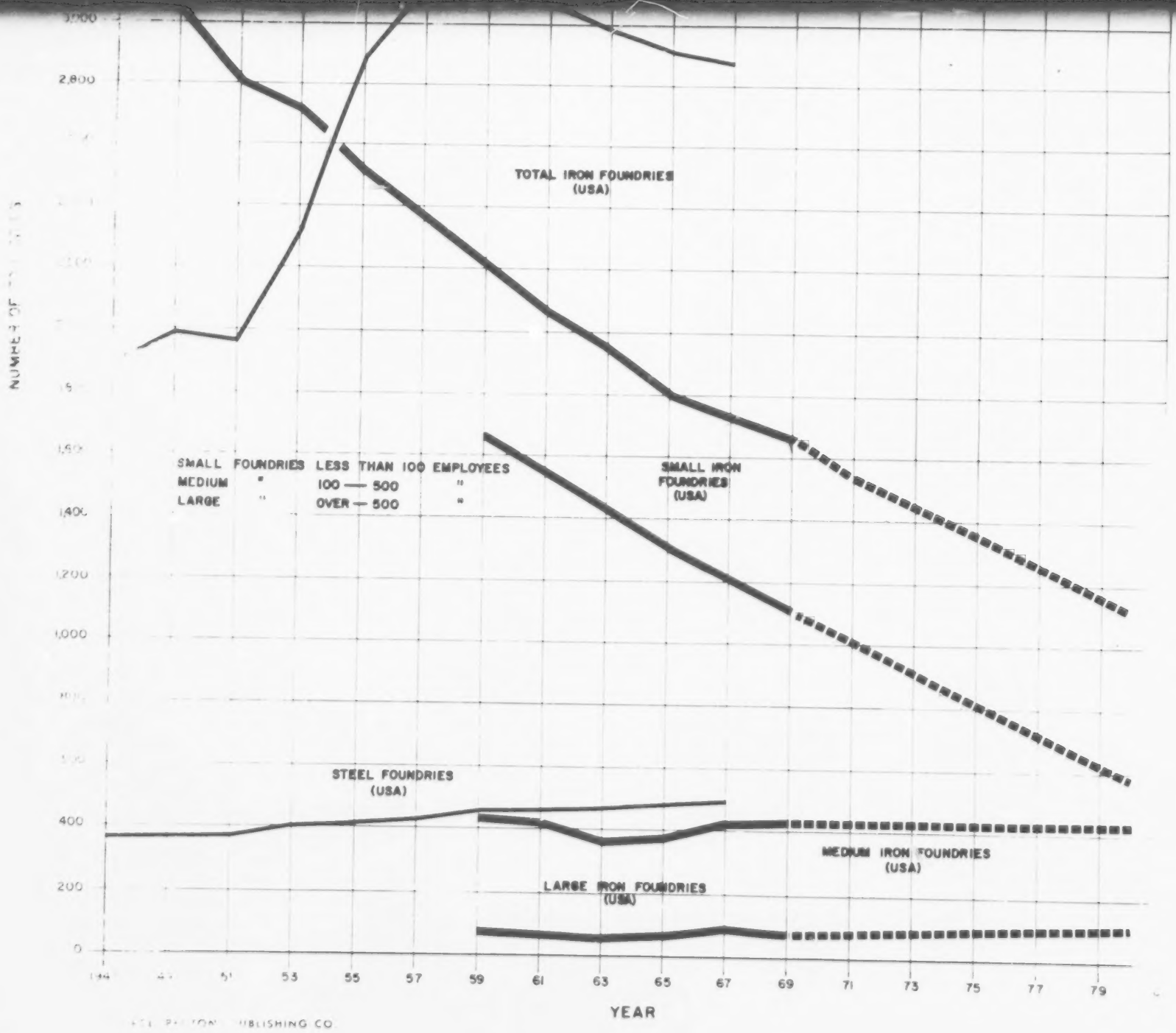
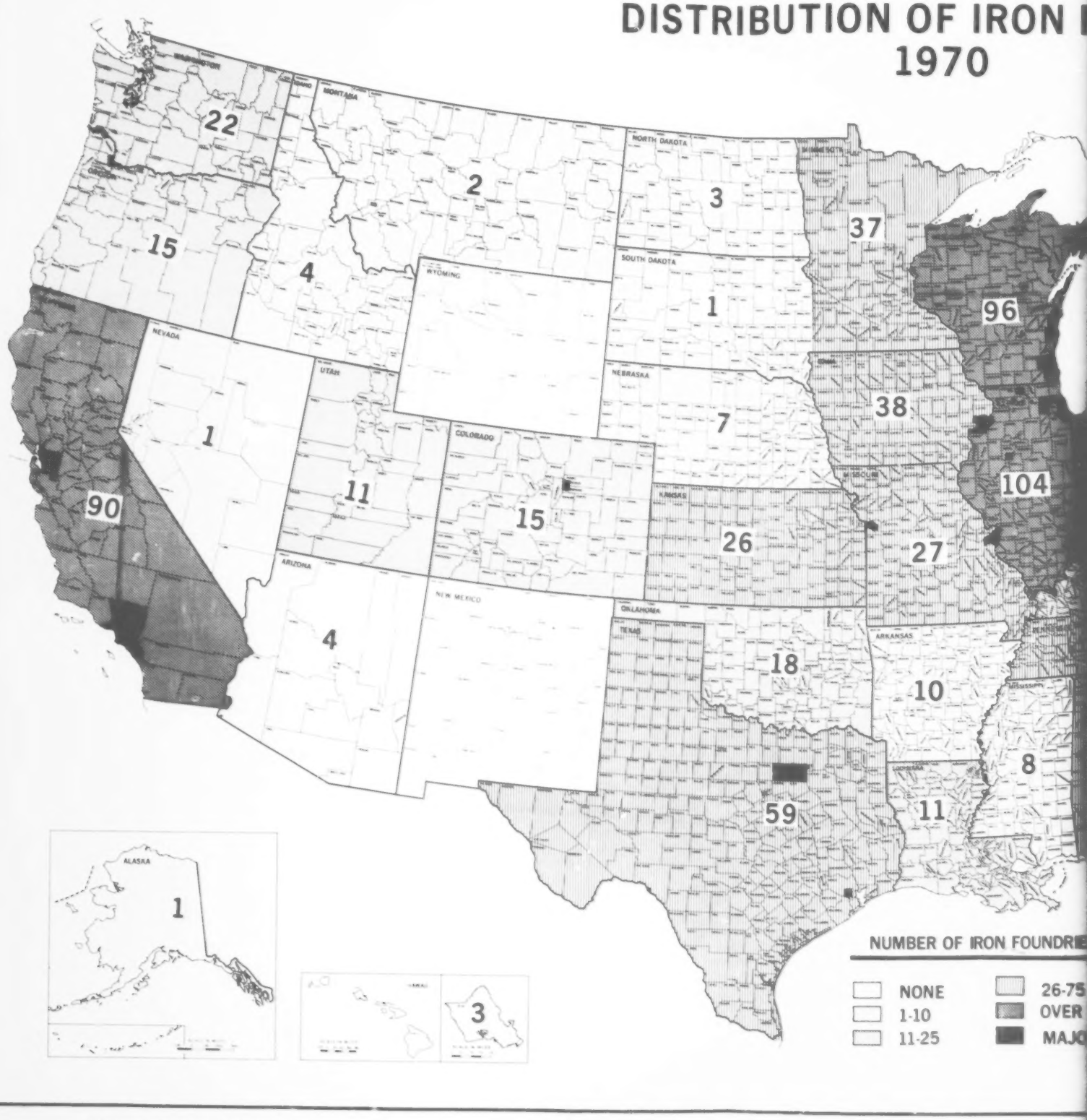

TOTAL IRON FOUNDRIES
(USA)
SMALL FOUNDRIES LESS THAN 100 EMPLOYEES
MEDIUM " 100 — 500 "
LARGE " OVER — 500 "
SMALL IRON
FOUNDRIES
(USA)
STEEL FOUNDRIES
(USA)
MEDIUM IRON FOUNDRIES
(USA)
LARGE IRON FOUNDRIES
(USA)
2,800
1,600
1,400
1,200
1,000
400
200
0
53
55
57
59
61
63
65
67
69
71
73
75
77
79
YEAR

EXHIBIT 18

DISTRIBUTION OF IRON F
1970



SOURCE: PENTON PUBLISHING CO

STRIBUTION OF IRON FOUNDRIES
1970

Reproduced from best available copy.

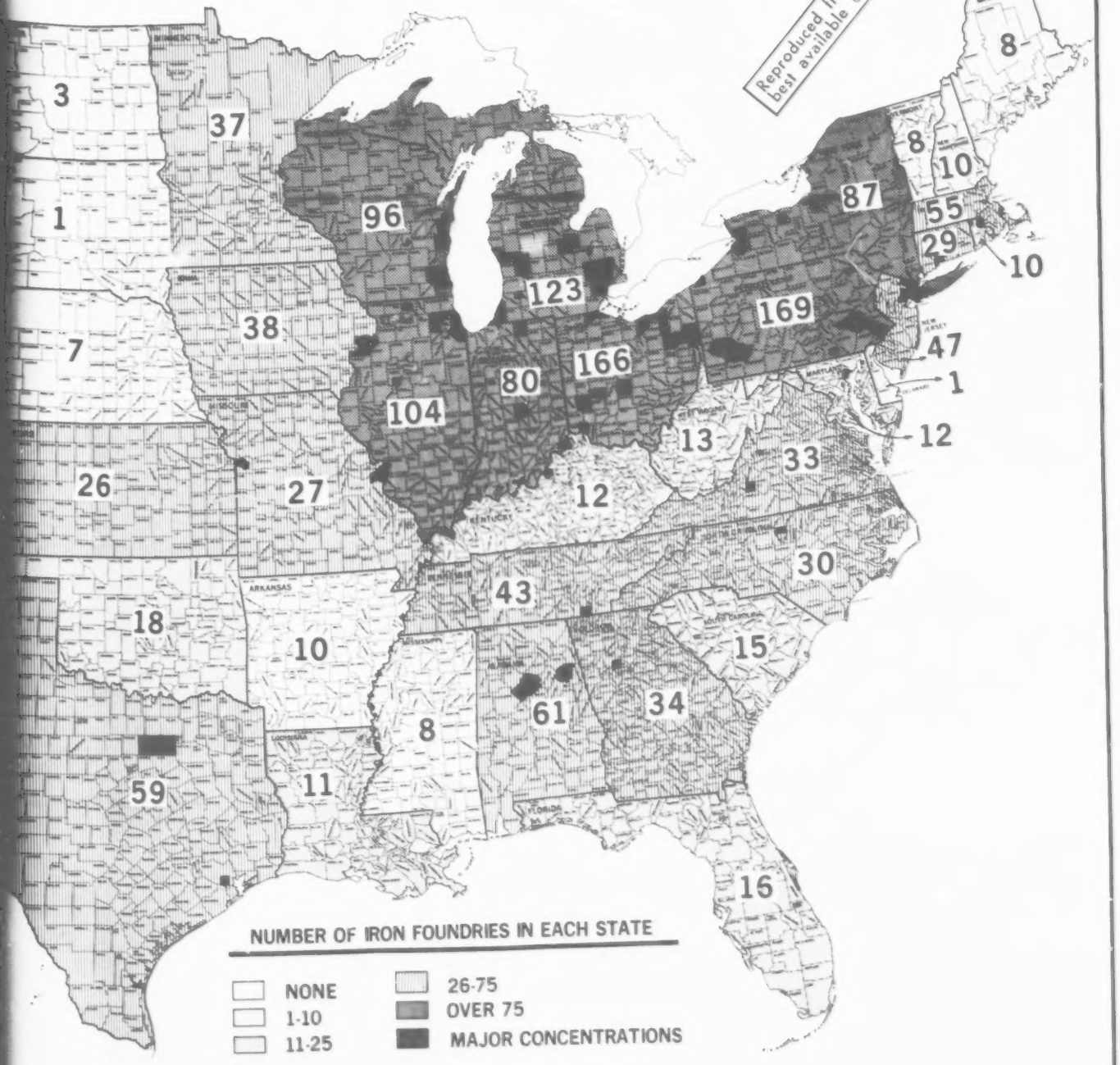


EXHIBIT 20

GEOGRAPHICAL DISTRIBUTION OF IRON FOUNDRIES

	Gray Iron				Ductile Iron				Malleable Iron			
	1969	1967	1965	1963	1969	1967	1965	1963	1969	1967	1965	1963
Alabama	56	56	59	65	17	16	17	12	2	3	2	2
Alaska	1	-	-	-	-	-	-	-	-	-	-	-
Arizona	4	3	3	4	1	-	-	-	-	-	-	-
Arkansas	10	11	10	10	1	1	1	1	-	-	-	-
California	88	86	95	102	29	23	24	23	1	1	1	4
Colorado	15	17	18	20	4	3	4	3	-	-	-	1
Connecticut	24	23	24	29	7	6	6	5	4	5	5	5
Delaware	1	2	2	2	-	-	-	-	-	-	-	-
District of Columbia	-	-	1	1	-	-	1	1	-	-	-	-
Florida	17	19	19	20	3	3	2	2	-	-	-	-
Georgia	32	29	32	35	8	6	6	7	-	-	-	-
Hawaii	3	4	3	3	-	-	-	-	-	-	-	-
Idaho	4	4	4	4	1	1	1	1	-	-	-	-
Illinois	97	104	107	113	32	31	29	28	9	10	11	11
Indiana	75	81	75	84	16	12	12	11	4	4	4	5
Iowa	36	37	38	43	8	6	5	5	1	2	1	2
Kansas	24	22	22	23	9	6	7	7	-	-	-	-
Kentucky	11	15	16	16	2	1	-	-	-	-	-	-
Louisiana	10	10	16	13	2	2	2	1	-	-	-	-
Maine	8	8	8	9	1	-	-	-	-	-	-	-
Maryland	13	12	13	14	5	3	2	2	1	1	1	1
Massachusetts	53	56	57	67	13	9	9	7	3	3	5	3
Michigan	114	122	127	133	36	32	28	28	7	8	6	6
Minnesota	36	35	35	38	8	5	4	3	2	1	1	1
Mississippi	7	7	8	8	-	-	-	-	-	-	-	1
Missouri	28	30	29	33	6	5	3	4	-	-	1	2
Montana	2	2	2	4	-	-	-	-	-	-	-	-
Nebraska	7	8	8	8	1	-	-	-	-	-	-	-
Nevada	1	1	1	1	-	-	-	-	-	-	-	-
New Hampshire	8	5	4	8	2	1	-	-	1	1	1	1
New Jersey	45	44	48	56	12	10	10	9	2	1	1	2
New Mexico	-	1	2	1	-	-	-	-	-	-	-	-
New York	82	88	97	103	17	16	19	17	9	7	10	7
North Carolina	30	33	36	41	7	5	4	6	-	-	-	-
North Dakota	3	2	2	2	-	-	-	-	-	-	-	-
Ohio	151	162	159	163	61	52	46	46	16	18	16	18
Oklahoma	17	14	14	17	12	6	6	5	-	-	-	-
Oregon	13	16	17	16	5	7	7	6	-	-	-	1
Pennsylvania	155	183	189	198	48	43	41	34	16	14	13	14
Rhode Island	8	9	9	10	2	1	1	2	1	1	1	1
South Carolina	15	16	15	17	4	5	5	2	-	-	-	-
South Dakota	1	2	2	3	-	-	-	-	-	-	-	-
Tennessee	41	45	48	52	7	8	7	5	1	-	-	-
Texas	56	63	61	68	18	17	11	8	1	1	1	2
Utah	11	9	10	10	5	4	5	5	-	-	1	-
Vermont	8	8	10	10	1	-	-	-	-	-	-	1
Virginia	33	34	37	37	7	5	5	3	-	-	-	-
Washington	21	21	23	23	8	7	6	5	1	1	1	1
West Virginia	12	12	12	13	5	4	2	2	1	1	1	1
Wisconsin	84	82	85	87	28	25	23	22	10	10	11	11
Wyoming	-	-	-	-	-	-	-	-	-	-	-	-
Total United States	1,571	1,653	1,712	1,837	459	387	361	328	93	93	95	104

Source: Foundry Magazine Census of Foundries.

IRON FOUNDRY STATISTICS BY STATE AND REGION

Region and State	Total	Production 1968 Tons(1)	Production 1970 Tons(2)	Percent of Total, 1970	Estimated(3) Iron Foundry Industry Employment	Number of (3) Iron Foundries with Cupolas	Number of(3) Cupolas in Operation	Number of(3) Iron Foundries with Arc Furnaces
New England	120	239,000	196,481	1.3%	5,179	101	145	7
Maine	8	8,000	6,367	*	250	8	11	0
New Hampshire	10	2,500	3,701	*	200	7	7	0
Vermont	8	9,000	7,403	*	350	7	13	1
Massachusetts	55	127,000	107,785	0.7	1,631	48	68	1
Rhode Island	10	39,500	34,207	0.2	518	10	18	1
Connecticut	29	53,000	37,018	0.3	2,230	21	28	4
Middle Atlantic	303	3,643,000	3,311,198	22.4%	50,111	238	316	40
New York	87	754,000	676,746	4.6	10,244	67	94	13
New Jersey	47	489,000	441,709	2.9	6,686	35	46	4
Pennsylvania	169	2,400,000	2,192,743	14.9	33,181	136	176	23
East North Central	569	8,453,000	6,986,562	47.2%	105,723	460	719	71
Ohio	166	2,317,000	1,929,544	13.0	29,199	133	197	19
Indiana	80	980,000	868,366	5.9	13,141	70	100	10
Illinois	104	1,562,000	1,243,629	8.4	18,821	80	114	14
Michigan	123	2,991,000	2,445,708	16.5	37,005	95	189	20
Wisconsin	96	603,000	499,315	3.4	7,557	82	119	8
West North Central	139	627,000	568,180	3.8%	9,485	118	149	13
Minnesota	37	148,000	132,358	0.9	2,003	31	36	3
Iowa	38	327,000	293,976	1.9	4,450	35	50	3
Missouri	27	120,000	111,050	0.8	1,680	23	31	5
Nebraska	7	6,500	5,033	*	400	6	6	1
Kansas	26	24,000	23,691	0.2	885	20	23	1
North Dakota	3	1,000	1,332	*	55	2	2	0
South Dakota	1	500	740	*	12	1	1	0
South Atlantic	154	485,000	427,431	2.9%	7,980	139	176	10
Delaware	1	1,000	740	*	15	1	1	0
Maryland	12	101,000	77,588	0.5	1,174	9	11	1
Virginia	33	173,000	144,471	1.0	2,187	30	42	3
West Virginia	13	46,000	55,081	0.4	833	11	13	1
North Carolina	30	101,000	93,135	0.6	1,409	29	34	0
South Carolina	15	30,000	27,247	0.2	412	15	20	1
Georgia	34	27,000	24,286	0.2	1,600	31	39	1
Florida	16	6,000	4,883	*	350	13	16	3
East South Central	124	2,327,000	2,109,395	14.2%	31,988	105	175	6
Kentucky	12	282,000	261,301	1.8	3,955	9	17	0
Mississippi	8	4,000	4,439	*	140	7	9	0
Alabama	61	1,808,000	1,643,213	11.1	24,866	52	93	4
Tennessee	43	233,000	200,422	1.3	3,027	37	56	2
West South Central	98	551,000	502,855	3.4%	7,854	73	88	5
Arkansas	10	4,000	8,878	*	375	8	11	1
Louisiana	11	12,000	9,623	*	146	9	9	0
Oklahoma	18	18,000	21,659	0.1	327	9	10	1
Texas	59	516,000	462,695	3.1	7,006	47	58	3
Mountain	37	249,000	231,040	1.6%	3,537	26	40	5
Montana	2	16,000	4,863	*	74	2	4	0
Colorado	15	65,000	71,669	0.5	1,087	10	14	2
Arizona	4	51,000	41,166	0.3	623	2	5	2
Utah	11	114,000	110,802	0.7	1,678	8	13	1
Nevada	1	Negligible	300	*	15	0	0	0
Idaho	4	3,000	2,220	*	60	4	4	0
New Mexico	0	0	0	0	0	0	0	0
Wyoming	0	0	0	0	0	0	0	0
Pacific	131	531,000	472,858	3.2%	7,955	77	105	20
Washington	22	20,300	15,103	0.1	475	15	23	8
Oregon	15	4,000	4,883	*	600	9	9	2
California	90	504,700	450,948	3.0	6,825	51	70	9
Hawaii	3	1,500	1,036	*	45	1	2	1
Alaska	1	500	888	*	10	1	1	0
Total	1,675	17,103,000	14,806,000	100.0%	229,812	1,337	1,913	177

Notes: (1) A. T. Kearney & Company, Inc. estimate based upon Department of Commerce, Bureau of the Census, Current Industr

(2) Foundry Magazine estimate derived from U.S. Bureau of Census and Department of Commerce Survey of Manufacturers

(3) Penton Publishing Co., 1970.

* Less than 0.1%.

EXHIBIT 21

IRON FOUNDRY STATISTICS BY STATE AND REGION

70 (2)	Percent of Total, 1970	Estimated(3) Iron Foundry Industry Employment	Number of (3) Iron Foundries with Cupolas	Number of(3) Cupolas in Operation	Number of(3) Iron Foundries with Arc Furnaces	Number of(3) Arc Furnaces in Operation	Cupola(3) Capacity Ton/Hour	Arc Furnace(3) Capacity Ton/Hour	Induction(3) Furnace Capacity Ton/Hour
6,481	1.3%	5,179	101	145	7	8	1,127	22	17
6,367	*	250	8	11	0	0	76	0	0
3,701	*	200	7	7	0	0	26	0	2
7,403	*	350	7	13	1	1	92	1	-
7,785	0.7	1,631	48	68	1	1	603	8	5
4,207	0.2	518	10	18	1	1	12-	1	0
7,018	0.3	2,230	21	28	4	5	206	12	10
1,198	22.4%	50,111	238	316	40	87	2,887	826	116
6,746	4.6	10,244	67	94	13	28	943	622	24
1,709	2.9	6,686	35	46	4	7	483	18	23
2,743	14.9	33,181	136	176	23	52	1,461	186	69
6,562	47.2%	105,723	460	719	71	163	8,295	1,101	226
9,544	13.0	29,199	133	197	19	37	2,091	597	92
3,366	5.9	13,141	70	100	10	21	895	40	23
3,629	8.4	18,821	80	114	14	34	1,311	129	40
5,708	16.5	37,005	95	189	20	56	2,838	297	34
9,315	3.4	7,557	82	119	8	15	1,160	38	37
8,180	3.8%	9,485	118	149	13	21	989	59	40
2,358	0.9	2,003	31	36	3	5	192	14	7
3,976	1.9	4,450	35	50	3	4	389	15	14
1,050	0.8	1,680	23	31	5	10	235	26	3
5,033	*	400	6	6	1	1	32	3	4
3,691	0.2	885	20	23	1	1	131	1	11
1,332	*	55	2	2	0	0	7	0	1
740	*	12	1	1	0	0	3	0	0
27,431	2.9%	7,980	139	176	10	17	1,910	70	39
740	*	15	1	1	0	0	2	0	0
77,588	0.5	1,174	9	11	1	1	468	7	2
4,471	1.0	2,187	30	42	3	6	444	47	6
55,081	0.4	833	11	13	1	1	120	1	6
23,135	0.6	1,409	29	34	0	0	267	0	8
27,24-	0.2	412	15	20	1	5	102	3	3
24,286	0.2	1,600	31	39	2	1	430	1	13
4,883	*	350	13	16	3	3	77	11	1
29,395	14.2%	31,988	105	175	6	11	1,819	553	27
31,321	1.8	3,955	9	17	0	0	135	0	0
4,439	*	140	7	9	0	0	25	0	0
23,213	11.1	24,866	52	93	4	8	1,178	535	9
20,422	1.3	3,027	37	56	2	3	481	18	18
22,855	3.4%	7,854	73	88	5	8	626	17	30
8,878	*	375	8	11	1	1	52	3	0
9,623	*	146	9	9	0	0	48	0	1
21,659	0.1	327	9	10	1	1	68	1	13
32,695	3.1	7,006	47	58	3	6	458	13	16
31,040	1.6%	3,537	26	40	5	11	271	46	11
4,883	*	74	2	4	0	0	31	0	0
21,669	0.5	1,087	10	14	2	3	113	15	9
31,166	0.3	623	2	5	2	6	21	25	1
10,802	0.7	1,678	8	13	1	2	96	6	1
300	*	15	0	0	0	0	0	0	0
2,220	*	60	4	4	0	0	10	0	0
0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0
72,858	3.2%	7,955	77	105	20	48	646	95	58
15,103	0.1	475	15	23	8	19	90	54	4
4,883	*	600	9	9	2	3	21	3	15
50,948	3.0	6,825	51	70	9	23	512	34	38
1,036	*	45	1	2	1	3	8	4	1
888	*	10	1	1	0	0	5	0	0
6,000	100.0%	229,812	1,337	1,913	177	374	18,570	2,789	564

mate based upon Department of Commerce, Bureau of the Census, Current Industrial Reports.

from U.S. Bureau of Census and Department of Commerce Survey of Manufacturers Data.

ANALYSIS OF THE IRON FOUNDRY INDUSTRY

	1970	1969	1968	1967	1966	1965	1964	1963	1962	1961	1960	1959
By Major Metal Cast:												
Gray and Ductile Iron	1,582	1,584		1,653		1,712		1,850		1,959		2,094
Malleable Iron	93	93		93		95		104		105		108
Total	1,677	1,677		1,746		1,807		1,954		2,064		2,202
By Employment(2)												
Over 1,000		31		32		24		20		20		20
500 to 999		40		54		41		41		40		37
250 to 499		109		105		90		95		113		95
100 to 249		297		299		287		276		289		290
50 to 99		374		411		393		408		420		444
20 to 49		419		421		461		511		542		582
Under 20		407		424		511		603		640		734
Total		1,677		1,746		1,807		1,954		2,064		2,202
By Employment(1)												
Over 1,000				23				17				
500 to 999				34				31				
250 to 499				85				73				
100 to 249				223				206				
50 to 99				227				228				
20 to 49				257				283				
Under 20				293				382				
Total				1,142				1,220				
By Type of Operation(1)												
Multiunit Companies				299				274				
Single Unit Companies				843				946				
Total				1,142				1,220				

Notes: (1) U.S. Department of Commerce, Census of Manufactures, SIC Codes 3321 and 3322.

(2) Foundry Magazine, adjusted by A. T. Kearney & Company, Inc. to exclude Canada.

EXHIBIT 22

ECONOMIC STATISTICS FOR THE IRON FOUNDRY INDUSTRY
(SIC 3321 AND 3322)

Year	Total Employment: Number x 10^3	Total Employment: Payroll ($ Millions)	Production Workers: Number x 10^3	Production Workers: Man-Hours (Millions)	Production Workers: Wages ($ Millions)	Value Added ($ Millions)	Value of Shipments ($ Millions)	Capital Expenditures ($ Millions)
1958	132.9	$ 631.8	113.1	209.4	$ 496.0	$ 938.4	$1,649.2	$ 37.0
1959	150.2	779.4	129.9	259.6	633.7	1,192.0	2,102.6	43.7
1960	145.0	753.1	124.0	236.9	601.7	1,138.7	1,998.7	66.1
1961	134.5	720.4	114.8	217.6	573.6	1,088.5	1,879.7	62.1
1962	141.8	812.3	121.9	242.4	651.9	1,272.1	2,140.9	69.5
1963	142.8	872.3	123.0	253.1	708.8	1,373.1	2,302.4	81.1
1964	150.0	984.4	130.0	278.1	808.9	1,572.6	2,632.9	94.9
1965	160.0	1,100.7	138.6	298.7	905.0	1,838.6	3,018.8	193.3
1966	167.1	1,169.6	144.6	306.8	956.0	1,941.2	3,177.6	251.8
1967	164.0	1,155.7	141.6	286.5	930.8	1,846.3	3,085.1	218.3
1968	162.6	1,258.4	139.8	290.3	1,027.8	2,154.5	3,378.9	195.7

Year	Ratio of Value Added to Shipments	Payroll per Employee (Dollars)	Wages per Production Worker (Dollars)	Value of Shipments per Production Worker (Dollars)	Man-Hours per Production Worker	Wages per Production Worker Man-Hour (Dollars)	Value Added Production Worker Man-Hour (Dollars)	Value Added per Dollar of Wages (Dollars)	Index of: (1968 = 100) Employment	Value Added	Shipments
1958	.569	$4,754	$4,385	$14,582	1,851	$2.37	$4.48	$1.89	81.7	43.6	48.8
1959	.567	5,189	4,878	16,186	1,998	2.44	4.59	1.88	92.4	55.3	62.2
1960	.569	5,194	4,852	16,118	1,910	2.54	4.81	1.89	89.2	52.8	59.1
1961	.579	5,356	4,996	16,374	1,895	2.64	5.00	1.89	82.7	50.5	55.6
1962	.594	5,728	5,348	17,563	1,988	2.69	5.25	1.95	87.2	59.0	63.4
1963	.596	6,108	5,763	18,719	2,058	2.80	5.42	1.94	87.8	63.7	68.1
1964	.597	6,563	6,222	20,253	2,139	2.91	5.65	1.94	92.2	73.0	77.9
1965	.609	6,879	6,530	21,781	2,155	3.03	6.16	2.03	98.4	85.3	89.3
1966	.610	6,999	6,611	21,975	2,122	3.12	6.33	2.03	102.8	90.1	94.0
1967	.598	7,047	6,573	21,787	2,730	3.25	6.44	1.98	100.9	85.7	91.3
1968	.637	7,739	7,352	24,169	2,076	3.54	7.42	2.10	100.0	100.0	100.0

Source: U.S. Department of Commerce, Industry Profiles 1958-1968, Washington, D.C., November, 1970.

EXHIBIT 23

EXHIBIT 24

COMPARISON OF IRON FOUNDRY ANNUAL SALES AND EMPLOYMENT

Value of Production	Percent Distribution of Foundries(1)	Number of Employees	Percent Distribution of Foundries(2)
Less than $500,000	47%	Less than 50	49%
$500,000 to $1,000,000	18	50 to 100	22
$1,000,000 to $2,500,000	18	100 to 250	18
$2,500,000 to $10,000,000	14	250 to 1,000	9
Greater than $10,000,000	3	More than 1,000	2

Sources: (1) BDSA-NAPCA Gray Iron Foundry Air Pollution BSDAF-807 1968.

(2) Foundry Magazine adjusted by A. T. Kearney & Company, Inc. to exclude Canadian foundries-1969 data.

EXHIBIT 25

AGE OF FOUNDRY EQUIPMENT

Units	Age of Units			
	0 to 5 Years	5 to 9 Years	10 to 19 Years	Over 20 Years
Cold Blast Cupolas	12	17	30	41
Hot Blast Cupolas	34	23	27	16
Reverberatory Furnaces	25	22	27	26
Channel Induction Furnaces	41	30	20	8
Coreless Induction Furnaces	52	20	17	5
Core and Mold Ovens	7	14	42	37
Vibrating Shakeouts	26	29	35	10
Airless Blast Units	24	24	39	13
Swing Frame Grinders (Wheel)	16	24	45	15
Floor Stand Grinders (Wheel)	17	22	46	15
Cutoff Grinders	30	38	29	3
Metal Cutting Bandsaws	16	31	44	9
Portable Grinders (Air)	45	35	18	1
Portable Air Chippers	43	34	21	2
Molding Machines (Green Sand)	15	18	48	19
Shell Mold Machines	34	39	27	-
Sand Throwers	10	22	45	23
Core Blowers and Shooters	14	27	41	18
Shell Core Machines	48	44	8	-
Hot Box Core Machines	60	40	-	-
Sand Rammers	31	39	26	3
Gas Fork Trucks	50	33	16	1
Bridge Cranes (Under 5 Tons)	20	27	30	22
Bridge Cranes (Over 5 Tons)	15	8	25	54
Direct Arc Furnaces	43	32	25	-

Source: 1968 Inventory of Foundry Equipment, Penton Publishing Co.

EXHIBIT 26

SUMMARY OF IRON FOUNDRY JOB CLASSIFICATIONS,
SKILL RANKING AND AVERAGE WAGE

Job Classification	Skill Ranking (1)	Skill Ranking (2)	Iron Foundry Hourly Wage (Dollars)	Industry Average(3) Percent in Classification
Melting Department				
Cupola Tender	277		$ 3.15	1.7%
Electric Furnace Tender	277	9.0	3.15	1.3
Molding and Coremaking				
Floor Molder	206	13.6	3.55	4.6
Bench Molder	169		3.35	1.3
Machine Molder	204		3.15	9.1
Sand Slinger Operator	169		3.35	0.7
Shell Machine Operator	169		3.05	2.9
Floor Coremaker	174	12.4	3.55	1.5
Bench Coremaker	159	7.8	3.35	2.6
Machine Coremaker	179	6.8	3.45	1.9
Core Assembler	144		2.87	2.7
Pouring				
Pourer	220		2.97	4.6
Sand Conditioning				
Sand Muller Operator	166	6.0	3.05	2.0
Cleaning and Finishing				
Blast Cleaner, Room	199	5.0	3.25	0.7
Blast Cleaner, Machine	164		2.97	1.8
Grinder	174	5.1	2.87	6.8
Chipper	179	7.1	3.15	9.6
Maintenance				
Electrician	259		3.85	1.8
Maintenance Man	269		3.55	6.3
Miscellaneous				
Patternmaker	249	16.7	4.05	2.4
Shakeout	145		2.87	5.3
Inspector	155		3.15	4.2
General Labor	200		2.77	15.3
Welder	202		3.45	3.1
Lift Truck Operator	150		3.15	3.1
Crane Operator	163		3.25	2.7

Notes: (1) Developed by A. T. Kearney & Company, Inc., from NEMA or NMTA Factory Job Evaluation Plan.

(2) Cooperative Wage Bureau, Benchmark and Specimen Example Job Descriptions and Classification.

(3) National Foundry Association, National Survey of Wages and Fringe Benefits in the Foundry Industry, January, 1971.

EXHIBIT 27

FINANCIAL IMPACT (MODEL DATA)

Particulars	New # / Old #	Model Plant Cases A (Under $.5 MM)	B ($1.0MM to $2.5 MM) C	C (Over $10.0 MM) E
Physical Characteristics				
Number of Cupolas		1	1	2
Melt Rate, Ton/Hour		4	8	16
Melt Time - Hour/Day		3	7	12
- Days/Year		175	225	250
- Total Hours		525	1,575	3,000
Ton Melted Annually - Gross		2,100	12,600	48,000
- Yield Percent		60.0%	65.0%	70.0%
- Net		1,260	8,180	33,600
Price per Net Ton Castings		$355	$151	$189
Cost per Net Ton Castings		$338	$141	$177
Financial Data				
Value of Shipments ($ 000)		$447	$1,228	$6,390
Total Cost and Expenses ($ 000)		$425	$1,145	$5,954
Profit before Tax - Amount		$22	$83	$436
- Rate		4.84%	6.78%	6.82%
Profit after Tax - Amount		$11	$42	$218
- Rate		2.46%	3.42%	3.42%
Investment		$234	$439	$2,739
Percent Investment of Total Assets(2)		82.1%	78.8%	76.3%
Total Assets		$284	$557	$3,580
Return on Assets (After Taxes)		3.9%(3)	7.5%(3)	6.1%(3)
Pollution Control Equipment Cost and Investment Factors				
Type of Equipment		Fabric Filter	Fabric Filter	Wet Scrubber
Investment - Amount		$51.5(1)	$131.6(1)	$262.2(1)
- Percent of Total Investment		22.1%	29.9%	9.6%
Annual Operating Cost - Amount		$17.7	$45.6	$95.4
- Percent Rate of Shipment		3.96%	3.71%	1.49%
Memo (Depreciation)(1)		$5.7(1)	$14.5(1)	$28.8(1)

Notes: (1) 9-year life straight line.
(2) CEQ Work Sheet II.
(3) Raw average - 5.8% ROA.

Source: U.S. Department HEW, Study AP-74 supplemented by CEQ material.

DATA FOR CONVERSION OF MEASUREMENT FROM RE
ON INVESTMENT TO RETURN ON TOTAL ASSETS(
($000 OMITTED)

Volume Group	Current Liabilities		Long-Term Debt		Equity	
	Amount	Percent of Total	Amount	Percent of Total	Amount	Perce of Tot
Foundries With Controls						
Under $500,000	$ 135	17.9%	$ 25	3.3%	$ 596	78.8
$1,000,000 to $2,500,000	3,588	21.2	709	4.2	12,670	74.6
Over $10,000,000	58,378	23.7	2,990	1.2	185,419	75.1
Foundries Without Controls						
Under $500,000	$2,585	23.7%	$ 763	7.0%	$ 7,564	69.3
$1,000,000 to $2,500,000	7,306	22.2	1,615	4.9	23,980	72.9
Over $10,000,000	4,540	25.2	5,162	28.6	8,329	46.2

Notes: (1) Source: Internal Revenue Service - Table A2.
Gross Receipts under Twice Foundry Sales.
(2) Investment = Equity plus Long-Term Debt.

EXHIBIT 28

SION OF MEASUREMENT FROM RETURN
TO RETURN ON TOTAL ASSETS(1)
($000 OMITTED)

Debt Percent of Total	Equity Amount	Equity Percent of Total	Total Assets or (L & N/W) Amount	Total Assets or (L & N/W) Percent of Total	Percent Investment of Total Assets (2)	Number of Cases	Average of Total Assets
3.3%	$ 596	78.8%	$ 756	100.0%	82.1%	4	$ 189
4.2	12,670	74.6	16,967	100.0	78.8	23	735
1.2	185,419	75.1	246,787	100.0	76.3	6	41,131
7.0%	$ 7,564	69.3%	$10,912	100.0%		60	182
4.9	23,980	72.9	32,901	100.0		38	864
28.6	8,329	46.2	18,031	100.0		2	9,015

COMPARISON OF COST STRUCTURES OF POLLUTION CONTROLLED VERSUS NON-CONTROLLED FOUNDRIES - BY VOLUME GROUP
(CUPOLA ARC ONLY)

UNDER $500,000
($000 OMITTED)

Financial Particulars	Controlled	Non-controlled	Adjustment for Pollution Costs: Explanation	Footnote Reference	Adjustment	As Adjusted	Adjustment to Reserve ROA: Explanation	Adjustment	As Adjusted	Adjusted to 15% ROA
Gross Receipts	$325	$264	Compensate for Increase in Revenue	(2)	$ 10.4	$274.4	Compensate in Revenue rise		$277.2	$280.7
Total Cost and Expenses - Amount	$314	$251	Introduce into cost 4.96% of sales for operating costs of pollution control devices	(1)	$ 10.4	$261.4	Maintain costs		$261.4	$261.4
- Percent Sales	96.6%	95.1%								
Profit before Taxes - Amount	$ 11	$ 13	Maintain profit $'s	(2)		$ 13			$ 15.8	$ 32.1
- Percent Sales	3.4%	4.9%				4.8%				
Taxes	$ 3	$ 4				$ 4	Main proportion of pretax to after tax profits		$ 4.9	$ 10.0
Profits after Taxes - Amount	$ 8	$ 9				$ 9	Increase profit		$ 10.9	$ 22.2
- Percent Sales	2.5%	1.4%				1.28%				
Depreciation, Depletion, Etc.	$ 10	$ 6	Annual depreciation pollution equipment or 5.7/17.7 x 10.4 = (See Work Sheet, table, page 2)		$ 1.4	$ 7.4			$ 7.4	$ 7.4
Cash Flow	$ 18	$ 11				$ 16.4			$ 18.3	$ 29.6
Total Asset	$189	$182	Introduce 22.1% of existing investment for pollution control	(3)	$ 40.1	$222.1	Maintain investment		$222.1	$222.1
Return on Total Assets (after Taxes)	4.2%	4.9%				4.05%	Restore ROA		4.9%	10.0%

Footnotes: Based on these data alone, the presently noncontrolled foundry:

(1) Is better off profit-wise than his controlled counterpart.

(2) Would suffer by installation of control equipment and would have his return-on-investment reduced to approximate his controlled counterpart (4.05% compared to 4.2%).

(3) Would suffer profit-wise (but not cash flow-wise) in the earlier years if accelerated depreciation were used.

Conclusion: If both had same price structure at the outset, the following price increases would be required:

Explanation	Gross	Increase: Amount (Cumulative)	Increase: Percent
Base	$264		
To cover costs increase	$274.4	$ 10.4*	3.94%
To restore ROA	$277.2	$ 13.2**	5.0%
To achieve 6% ROA	$293.6	$ 29.6**	11.2%

Notes: * May not shift business to competition.

** Could shift business to competition.

EXHIBIT 29

COMPARISON OF COST STRUCTURES OF POLLUTION CONTROLLED
VERSUS NON CONTROLLED FOUNDRIES - BY VOLUME GROUP

$1.0 MM TO UNDER $2.5 MM
($000 OMITTED)

Financial Particulars	Controlled	Non-controlled	Adjusted for Pollution Costs: Explanation	Footnote Reference	Adjustment	As Adjusted	Adjustments to Restore ROA: Explanation	Adjustment	As Adjusted	Adjusted to 10% ROA
Gross Receipts	$1,876	$1,733	Compensate in revenue	(2)		$1,793	Compensate in revenue		$1,828.0	$1,849
Total Costs and Expenses - Amount	$1,719	$1,620	Introduce into costs 93.7% of sales for operating costs of pollution control	(1)	$60	$1,680	Maintain costs		$1,680	$1,680
- Percent Sales	92.8%	93.5%								
Profit before Tax - Amount	$135	$111	Maintain profit dollars	(2)		$113			$148.0	$169
- Percent Sales	7.2%	6.5%								
Taxes	$57	$38				$38	Maintain proportion of pretax to after tax profits	$12.0	$50.0	$62
Profits after Taxes - Amount	$78	$73				$73		$22.5	$98.0	$112
- Percent Sales	4.2%	4.3%				4.18%				
Depreciation, Depletion, Etc.	$33	$52	Annual depreciation for pollution equipment is $763.6 x 60 = (EDP Work Sheet, table, page 2-supplementary data)		$19	$71			$71	$71
Cash Flow	$111	$127				$146			$169.0	$183
Total Assets	$715	$866	Introduce 29.9% of existing investment for pollution control	(1)	$760	$1,126	Maintain Investment		$1,126	$1,126
Return on Total Assets (after Taxes)	10.3%	8.7%				8.7%	Restore ROA		8.7%	10.0%

Footnotes: Based on these data alone, the presently noncontrolled foundry:

(1) Appears to be at some existing disadvantage profit-wise compared to its controlled counterpart due possibly to management, regional factors or simply a function of the averages.

(2) Would suffer by installation of control equipment but could possibly offset cost, restore its previous ROA or even achieve a 10% ROA without price increases which clearly would shift business to competitors.

(3) Would need to raise 29.9% more capital to install equipment which is not unmanageable.

Conclusion: If both had same price structure at the outset, the following price increases would be required:

Explanation	Gross	Increase: Amount (Cumulative)	Increase: Percent
Base	$1,733		
To cover costs increase	$1,793	$ 60*	3.47%
To restore ROA	$1,828	$ 95**	5.49%
To achieve 10% ROA	$1,849	$116**	6.7%

Notes: * May not shift business to competitor.

** Could shift business to competitor.

EXHIBIT 8

COMPARISON OF COST STRUCTURES OF POLLUTION CONTROLLED
VERSUS NON-CONTROLLED FOUNDRIES - BY VOLUME GROUP

OVER $10,0 00
($000 OMITTED)

Financial Particulars	Controlled	Non-controlled	Adjusted for Pollution Costs: Explanation	Footnote Reference	Adjustment	As Adjusted	Explanation to Restore ROA: Explanation	Adjustment	As Adjusted	Adjusted to 10% ROA
Gross Receipts	$61,722	$21,162	Compensate to Revenue	(2)		$21,467			$21,531	$22,097
Total Costs and Expenses - Amount	$58,926	$20,464	Introduce into costs 1.49% of sales for operating costs of pollution control	(1)	$305	$20,769	Maintain costs		$20,769	$20,769
- Percent Sales	95.4%	96.7%				96.7%				
Profits before Tax - Amount	$2,796	$698	Maintain profit dollars	(2)		$698			$762	$1,328
- Percent Sales	4.6%	3.3%				3.3%	Maintain proportion of pretax to after tax profits			
Taxes	$1,826	$179				$179			$196	$340
Profits after Taxes - Amount	$970	$519				$519	Restore 12.4% ROA	$47	$566	$988
- Percent Sales	1.6%	2.4%				2.4%				
Depreciation, Depletion, etc.	$2,201	$569	Annual depreciation for pollution equipment 28.8/95.4 x $305		$92	$661			$661	$661
Cash Flow	$3,171	$1,088				$1,180			$1,207	$1,629
Total Assets	$41,111	$9,015	Introduce 9.6% of existing investment into net worth for pollution equipment	(3)	$865	$9,880			$9,880	$9,880
Return on Total Assets (after Taxes)	6.0%	5.7%				5.2%	Restore ROA		5.7%	10.0%

Footnotes: Same as Exhibit 30.

Conclusion. If both had same price structure to begin with, the following price increases would be required:

Explanation	Gross	Increase Amount (Cumulative)	Percent
Base	$21,162		
To cover cost increase	$21,467	$305*	1.44%
To restore ROA	$21,531	$369*	1.74%
To achieve 10% ROA	$22,097	$935*	4.4%

Note: * Probably would not shift any business.

EXHIBIT 31

EXHIBIT 32

AVERAGE SELLING PRICE OF CAST IRON PRODUCTS, 1968

Product	Average Price Dollars/Ton(1)
Ingot Molds	100
Cast Iron Pressure Pipe and Fittings	145
Cast Iron Soil Pipe and Fittings	166
Miscellaneous Gray Iron Castings	322
Malleable Iron Castings	450

Note: (1) Developed from U.S. Department of Commerce, Bureau of the Census, Current Industrial Reports, 1969 Summary.

EXHIBIT 33

PIPE USAGE BY MATERIAL AND TYPE OF SERVICE

Material Type	Water Distribution (000 Feet)	Sewer Collection (000 Feet)	Drain, Waste, Ventilation (000 Feet)
Metallic Piping			
Steel	65,329		83,124
Copper	98,305		48,626
Cast Iron	83,465	46,832	163,884
Aluminum			
Other			473
Nonmetallic Piping			
Plastic	206,681	21,719	30,007
Vitrified Clay		162,039	15,500
Concrete	3,320	55,079	11,273
Asbestos-Cement	53,605	39,260	8,701
Bituminous Fiber		43,061	
Other			1,358

Material Type	Water Distribution Index C.I. = 100	Sewer Distribution C.I. = 100	Drain, Waste, Ventilation C.I. = 100
Metallic Piping			
Steel	78	-	51
Copper	118	-	30
Cast Iron	100	100	100
Aluminum	-	-	-
Other	-	-	Negligible
Nonmetallic Piping			
Plastic	248	46	18
Vitrified Clay	-	346	10
Concrete	4	118	7
Asbestos Cement	64	84	5
Bituminous Fiber	-	92	-
Other	-	-	1

Source: 1967 A. T. Kearney & Company, Inc. market study.

COMPARISON OF COST OF CAST IRON
COMPETING PRODUCTS

PRESSURE PIPE

Pipe Size	Cast Iron(1) Material	Cast Iron(1) Installation(2)	Cast Iron(1) Total	Steel(3) Material	Steel(3) Installation	Steel(3) Total(4)	Copper			Material
2"										0.80
3										1.25
4	2.15	3.00	5.15	2.17	4.81	8.13				
5				3.53	5.45	11.13				2.15
6	3.05	3.75	6.80	4.40	6.44	13.25				3.50
8	4.35	5.00	9.35	5.83	9.74	19.76				
10	5.70	6.50	12.20	8.71	12.82	29.43				
12	7.25	8.10	15.35							
14	9.15	8.95	18.10							
15										
16	10.85	10.65	21.50							
18										

SOIL PIPE

Pipe Size	Cast Iron Material	Cast Iron Installation(2)	Cast Iron Total	Plastic(5) Material	Plastic(5) Installation	Plastic(5) Total	Vitrified Clay(7) Material	Vitrified Clay(7) Installation(2)	Vitrified Clay(7) Total	Material
2"										
3										
4	2.50	3.35	5.85	2.70	1.85	4.55	0.65	1.00	1.65	
5										
6	4.25	4.75	9.00				0.85	1.30	2.15	0.95
8	7.40	7.00	14.40				1.20	1.55	2.75	1.05
10							1.90	1.90	3.80	1.20
12							2.40	2.30	4.70	
14										
15										
16										
18										

All prices are dollars per linear foot.

Notes: (1) Class 150, Mechanical Joint Pressure Pipe.

(2) Excavation or backfill not included.

(3) Schedule 40, Welded Joints.

(4) Includes fittings and hangers.

(5) Schedule 40.

(6) Class 2400.

(7) Premium Joint, Extra Strength ASTM C-200.

(8) 150 psi.

(9) From Continental Concrete Pipe Corp., ASTM Class III, w/gaskets.

Source: Building Construction Cost Data, 1971.

EXHIBIT 34

COMPARISON OF COST OF CAST IRON PIPE WITH COMPETING PRODUCTS

PRESSURE PIPE

Copper		Plastic			Concrete			Asbestos-Cement(8)		
		Material	Installation	Total	Material(9)	Installation	Total	Material	Installation(2)	Total
		0.80	0.80	1.60						
		1.25	0.90	2.15				1.00	0.70	1.70
		2.15	1.00	3.15				1.35	0.75	2.10
		3.50	1.50	5.00	2.15	1.00	3.15	2.00	0.90	2.90
					2.50	1.15	3.65	2.90	1.05	3.95
					2.95	1.50	4.45	3.80	1.30	5.10
								5.00	1.50	6.50
					3.95					
					4.90	2.15	7.05	8.10	2.30	10.40

SOIL PIPE

ed Clay(7)		Concrete			Asbestos Cement(6)			Bituminous Fiber		
llation(2)	Total	Material	Installation(2)	Total	Material	Installation(2)	Total	Material	Installation(2)	Total
1.00	1.65							0.40	0.40	0.80
								0.85	0.40	1.25
1.30	2.15	0.95	1.00	1.95	1.00	0.80	1.80	1.00	0.45	1.45
1.55	2.75	1.05	1.15	2.20	1.25	0.95	2.20	2.50	0.45	2.95
1.90	3.80	1.20	1.30	2.50	1.80	1.10	2.90			
2.30	4.70				2.30	1.30	3.60			